Data From the Skies Warn of Disasters on the Ground

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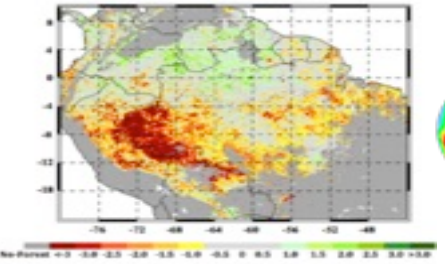
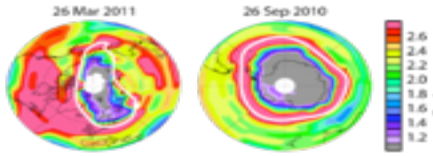
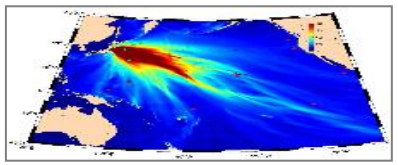
About NASA Programs
Observations
Earthquakes
Wildfires

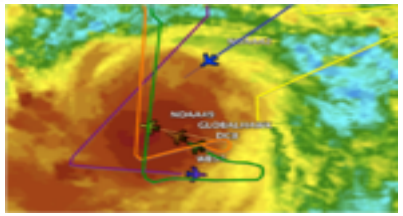
NASA Earth Science Division

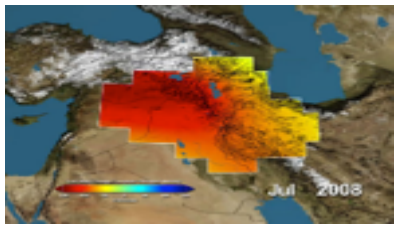
Research

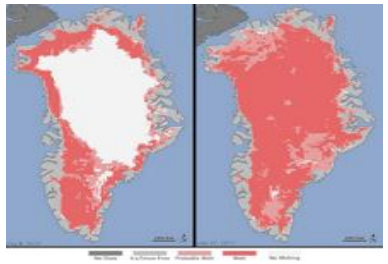




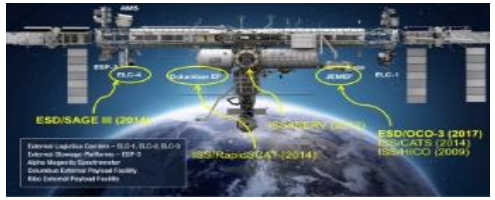


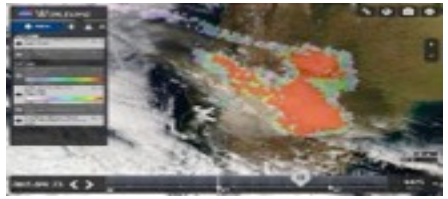




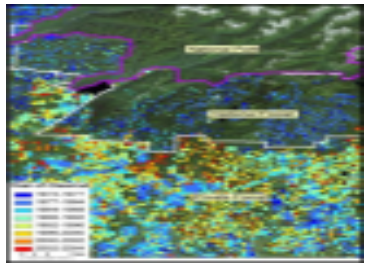


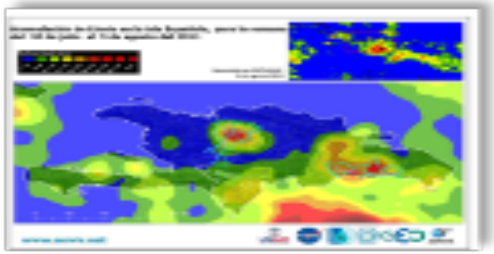
Flight

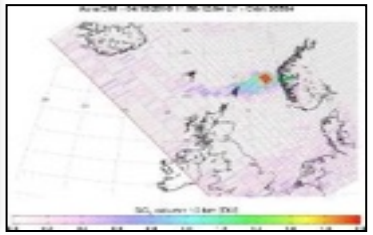


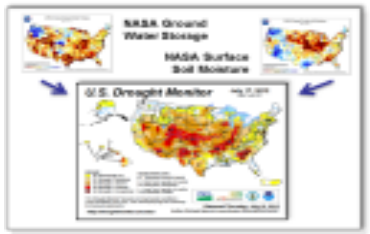


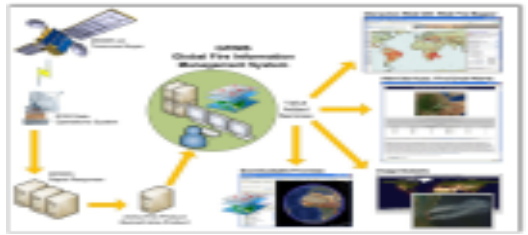
Applied Sciences

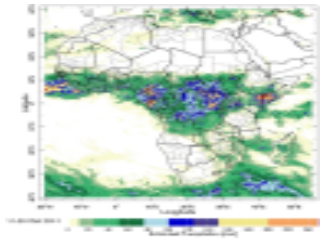




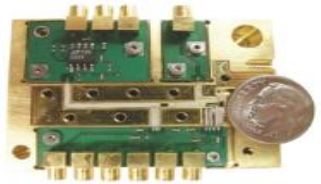


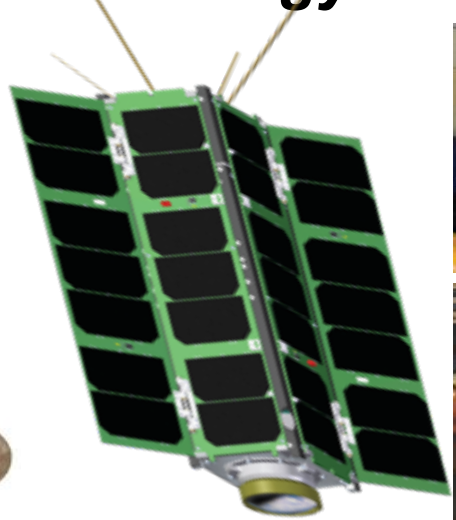






Technology





Applications Themes & Societal Benefit Areas

Emphasis in 4 Applications Areas

Health & Air Quality

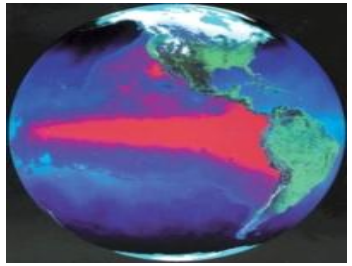
Water Resources

Disasters

Ecological Forecasting

Support opportunities in 5 additional areas

Agriculture



Climate

Weather

Energy

Oceans

Crosscutting theme: Wildland Fires

NASA Applied Science: Disasters

NASA's Earth Science DISASTERS

https://disasters.nasa.gov
https://maps.disasters.nasa.gov

The Disasters Applications area promotes the use of Earth observations to improve prediction of, preparation for, response to, and recovery from natural and technological disasters. Disaster applications and applied research on natural hazards support emergency preparedness leaders in developing mitigation approaches, such as early warning systems, and providing information and maps to disaster response and recovery teams.

- The Program targets a spectrum of disasters, including floods, earthquakes, volcanoes, and landslides as well as combined hazards and cascading impacts.
- The Program has Coordinators at NASA HQ and across NASA Centers to enable generation and delivery of data and products to end-users during disaster event activations.
- Since NASA is not an operational agency, the Disasters Program activates during an event upon an end-user request
- Products are shared directly to the end-user, posted to the Disasters website, and through the Disasters Geoportal.


Earthquakes


Volcanoes


Landslides

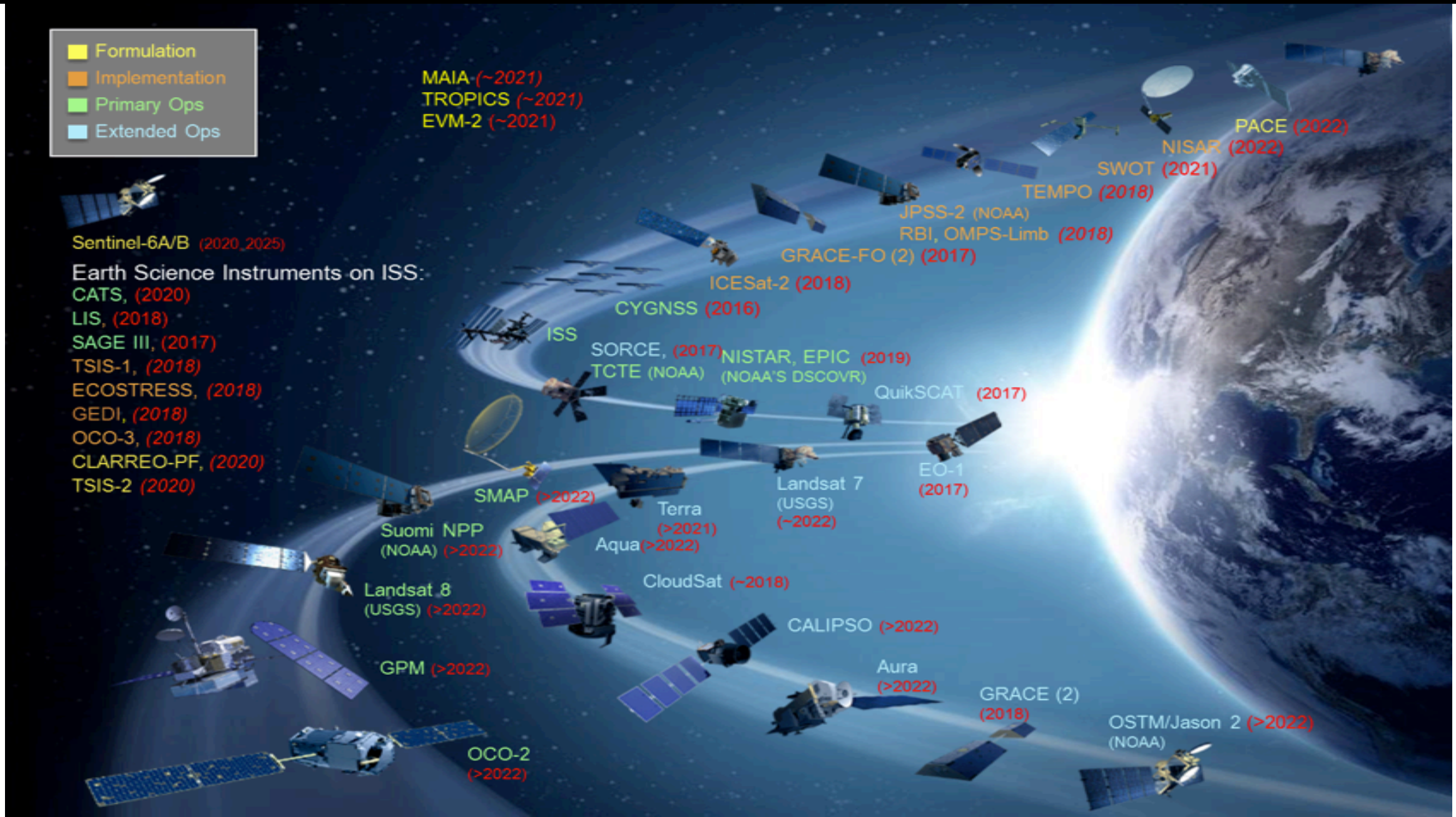

Floods


Fires


Land Subsidence

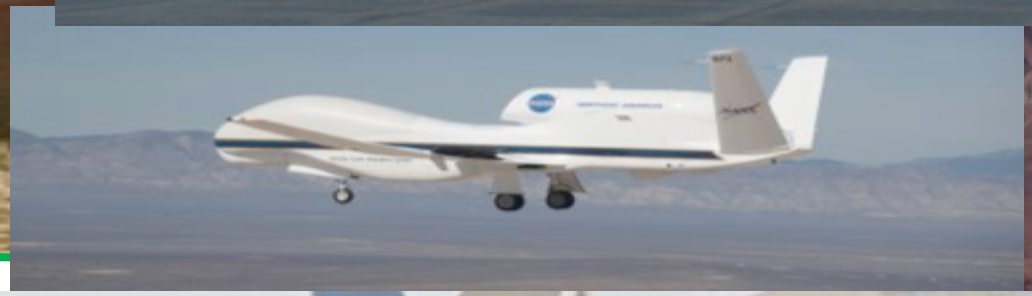
Space and Airborne Observations

NASA Satellite Constellation



NASA Airborne Science Fleet

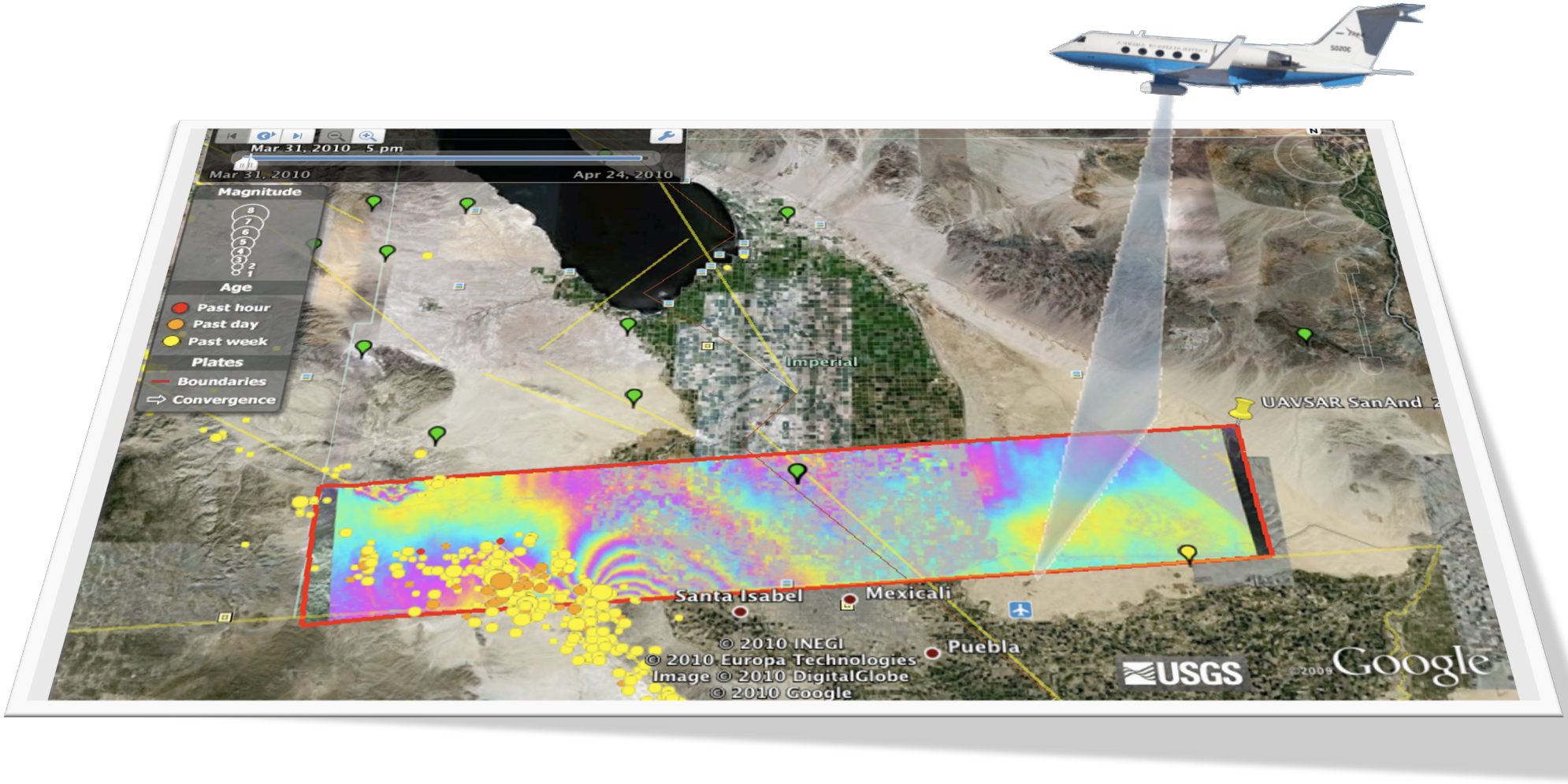
https://airbornescience.nasa.gov/



UAVSAR

- NASA's Airborne Interferometric Synthetic Aperture Radar Platform
- Flown on a Gulfstream-III
- 12.5 km altitude
- Repeat pass interferometry

UAVSAR/InSAR



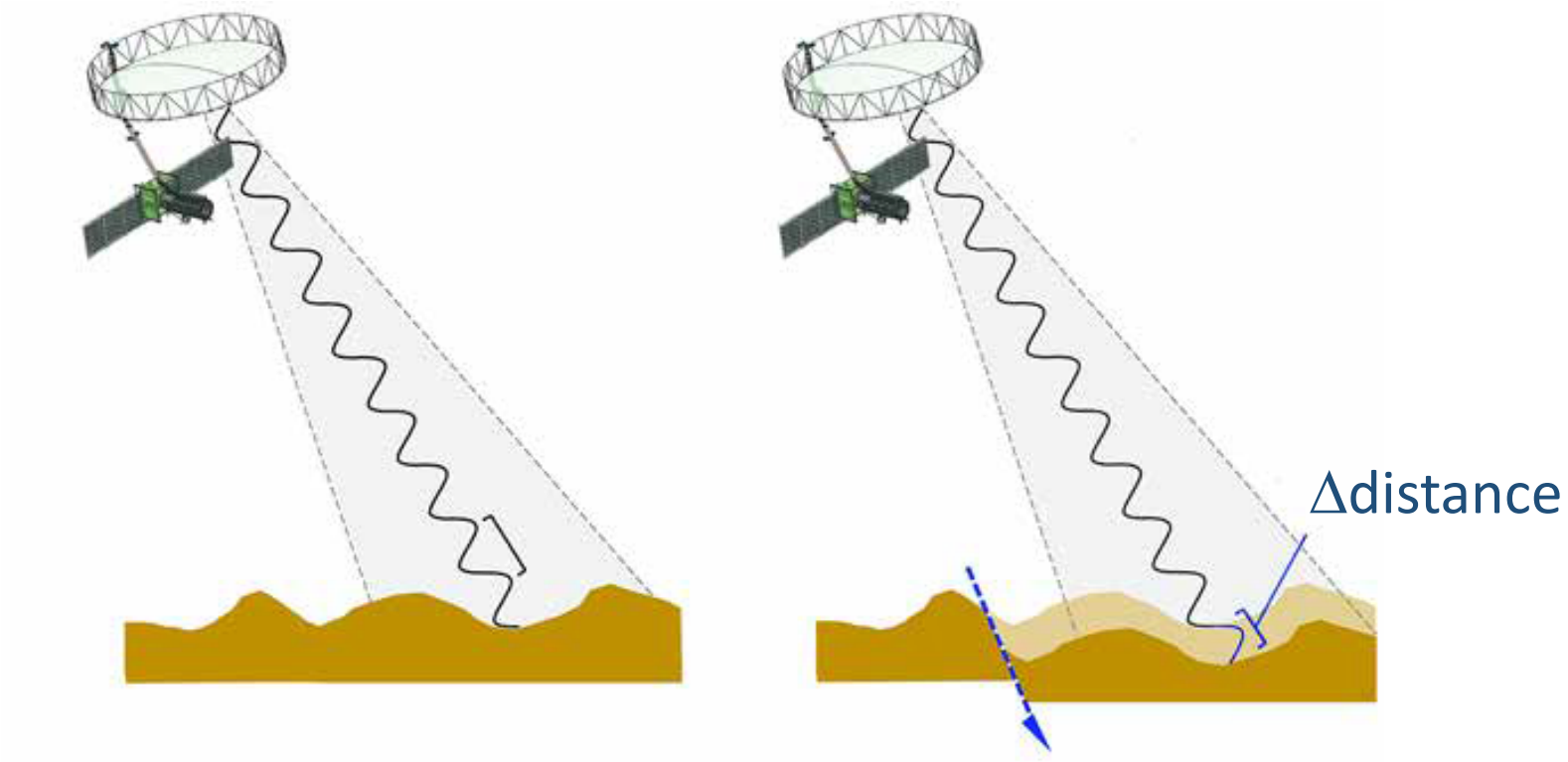
Products provide ground changes in a line of sight direction to/from the instrument

UAVSAR/InSAR

UAVSAR

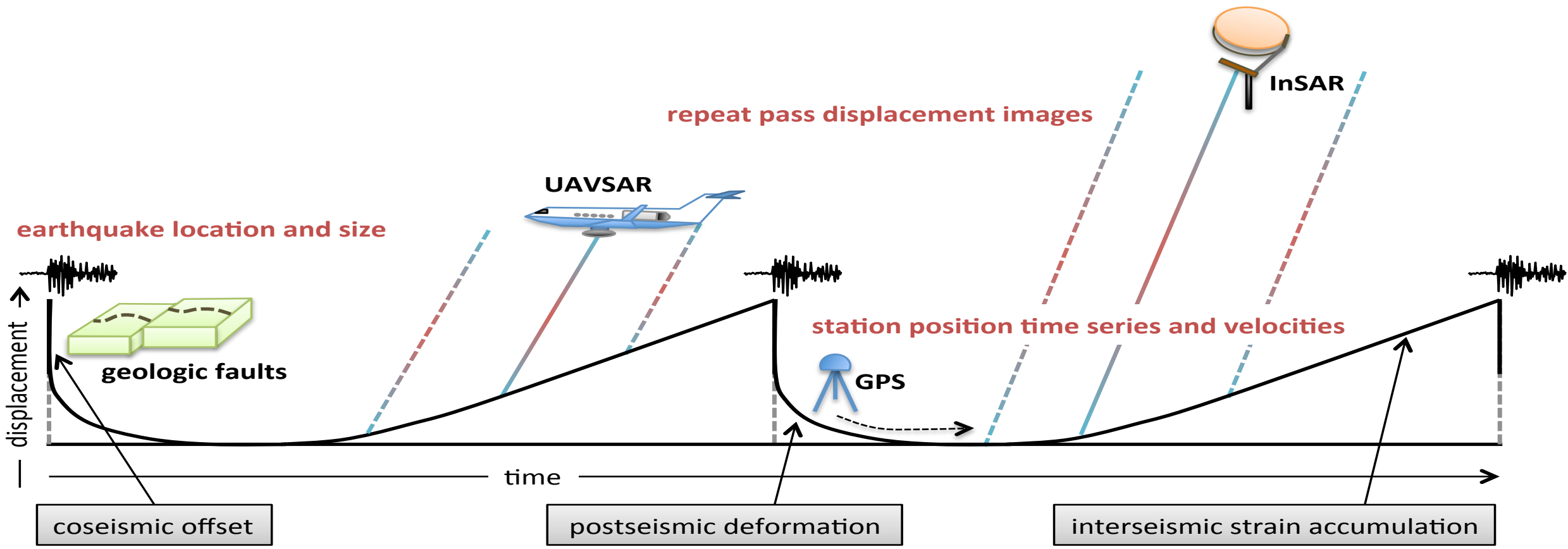
- Airborne InSAR
- L-band (24 cm wavelength)
- Repeat pass interferometry
- Flown on a Gulfstream III
- Color cycle is 12 cm

InSAR Measures Phase Difference



Converted to line of sight range change measurement

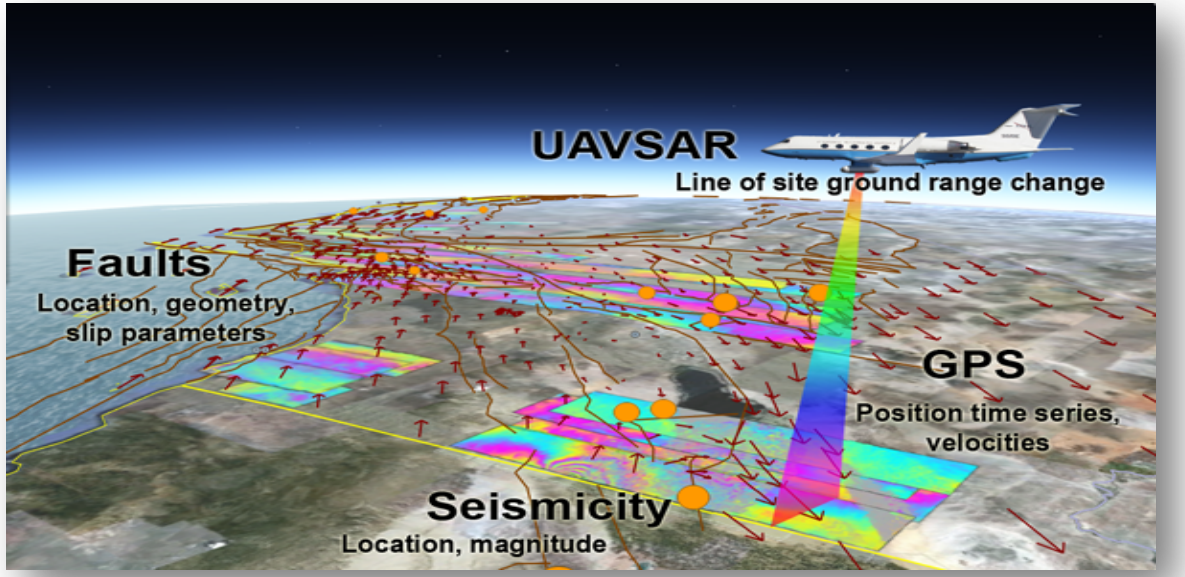
Geodesy Observes the Earthquake Cycle

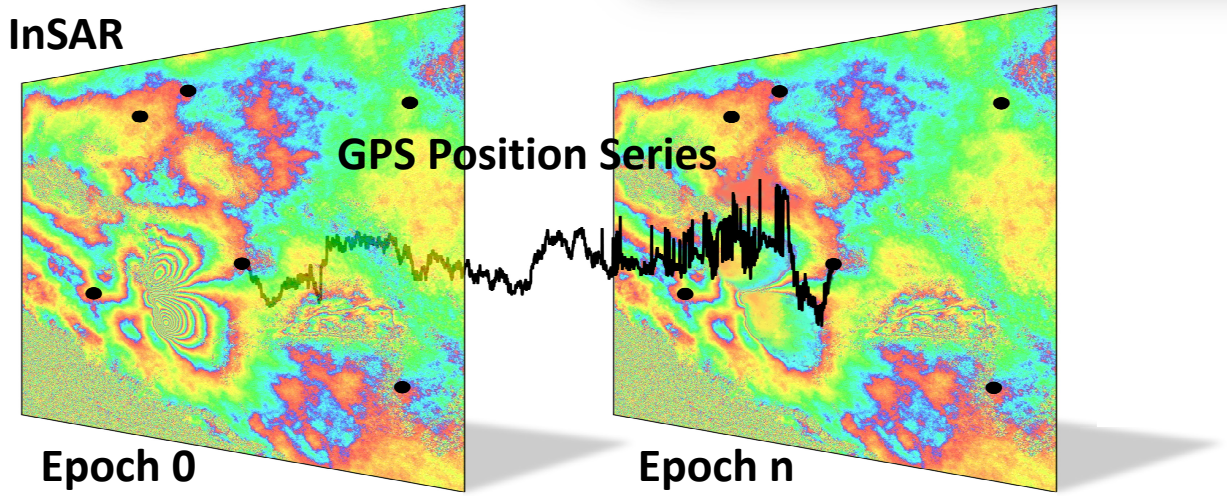


Strain accumulation and release

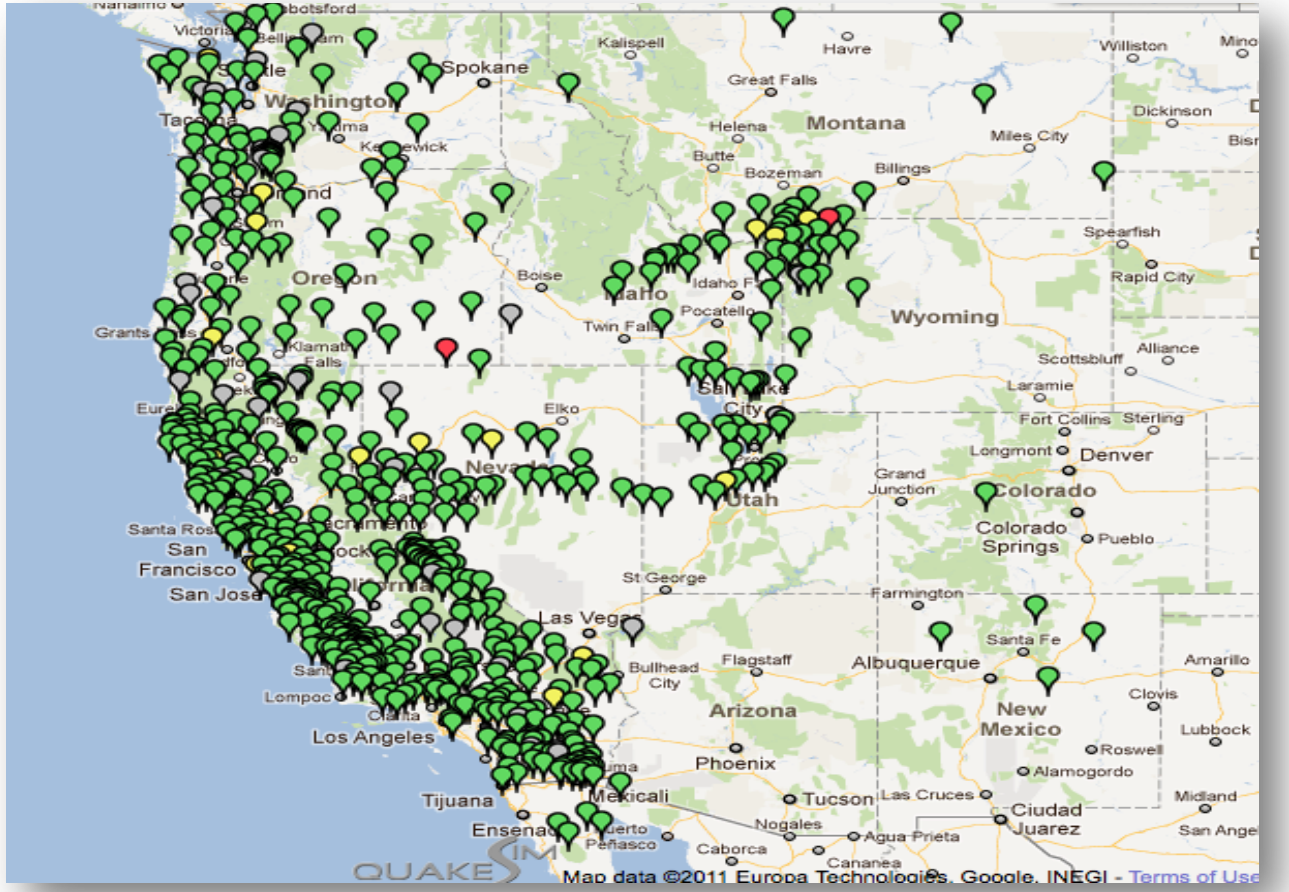
Geodetic Imaging Products

- GPS
  - Smooth in time, not space
- InSAR
  - Smooth in space, not time



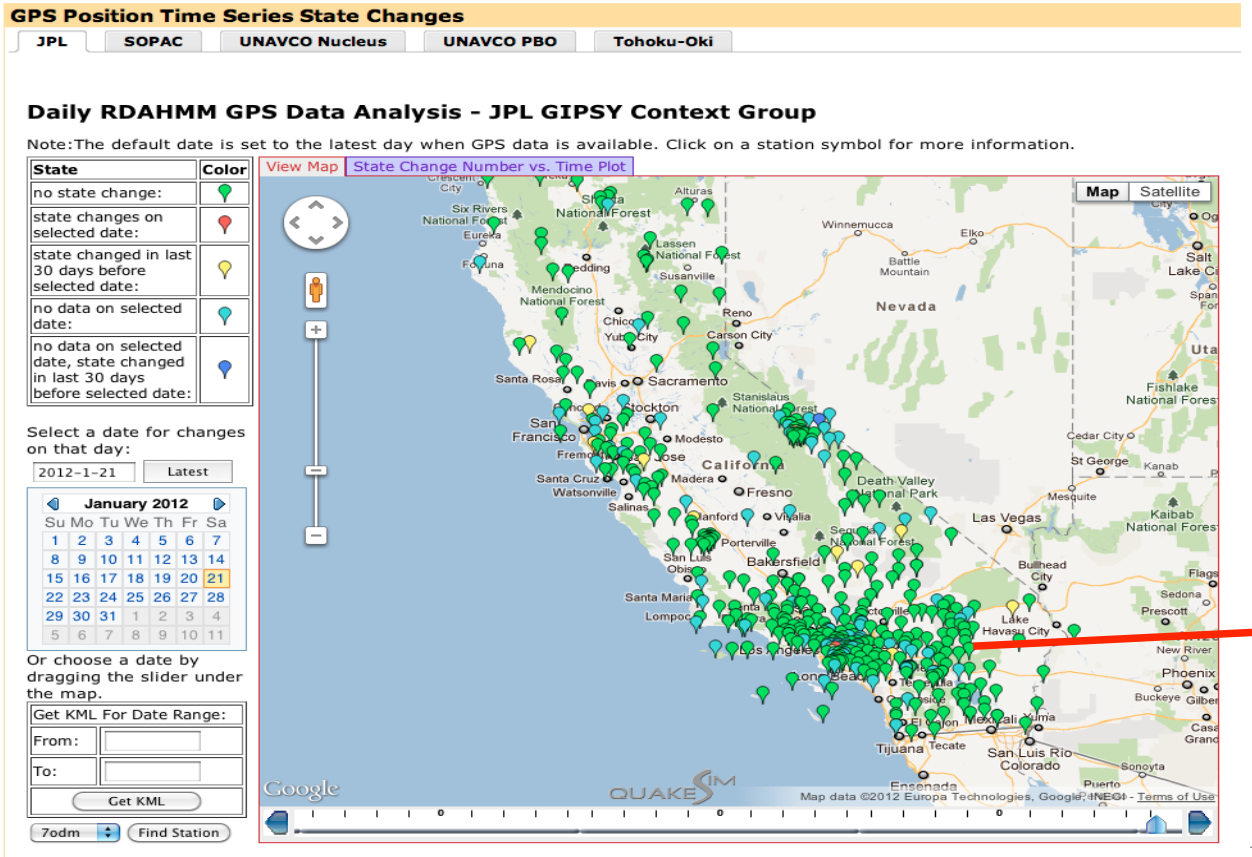


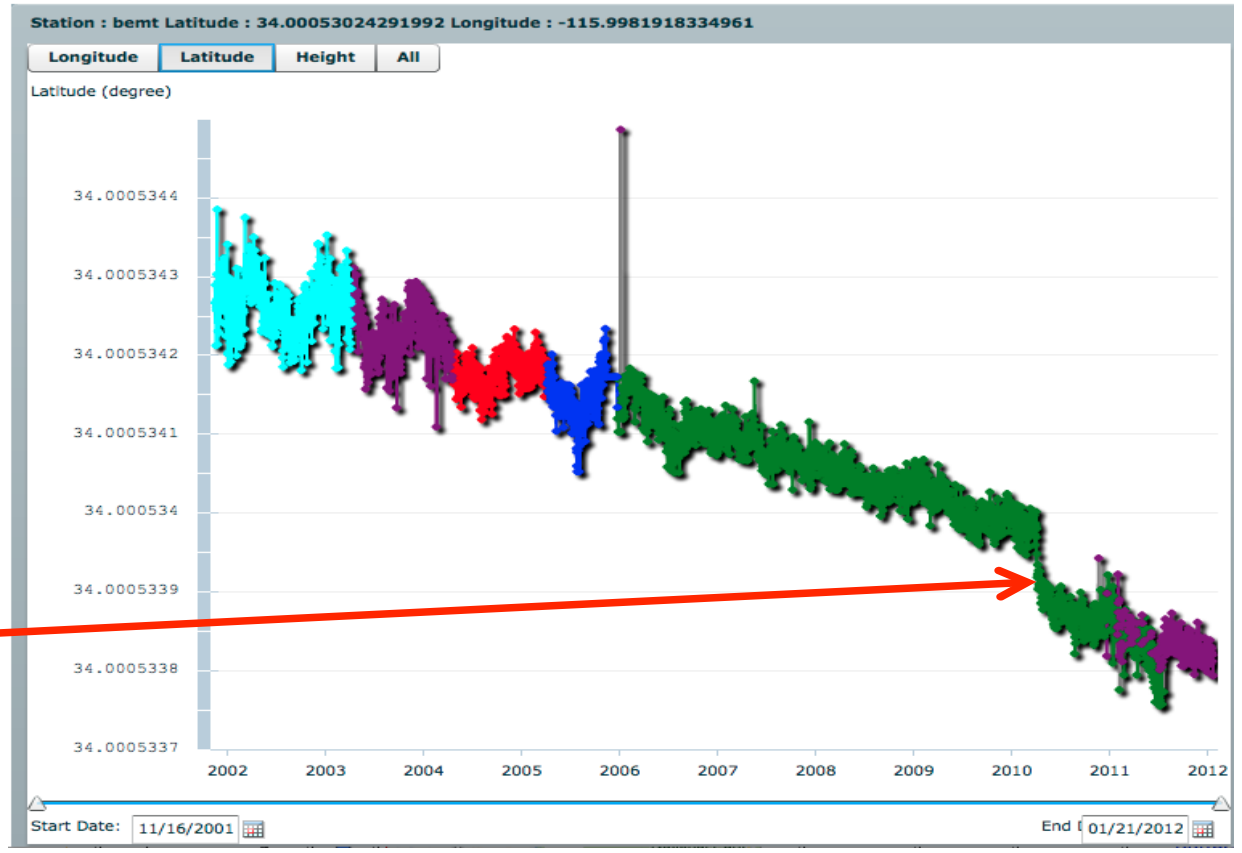
GPS



Horizontal position accuracy 1 mm
Vertical position accuracy 2 mm
1 mm/yr horizontal velocities

GPS Position Time Series Analysis



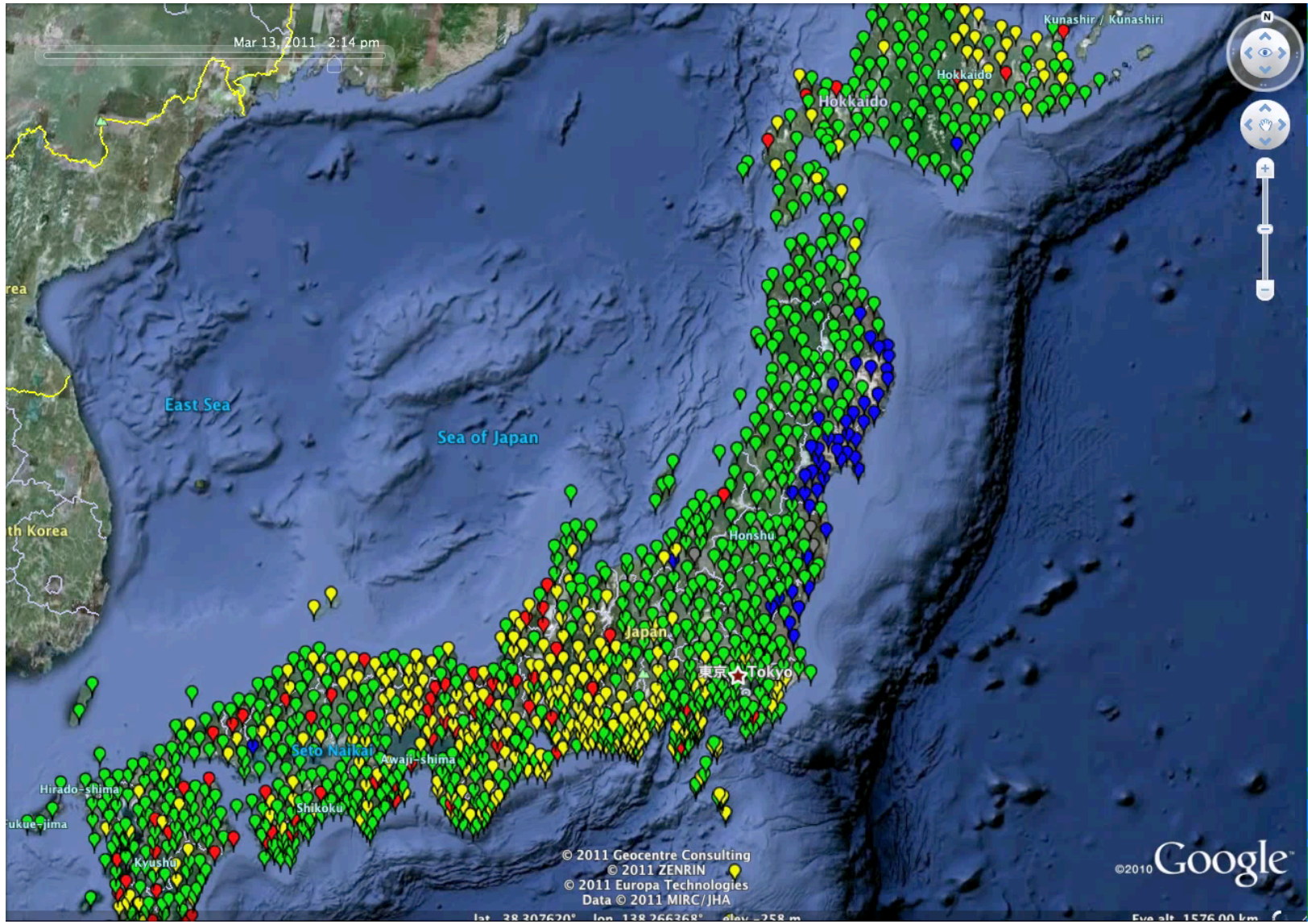


Substantial postseismic motion northeast of the El Mayor – Cucapah Rupture

California GPS Deformation

GPS Station State Changes in the Tohoku-oki Earthquake

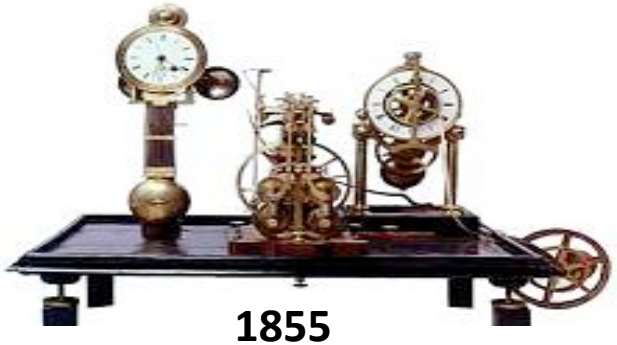
- GPS station state can be analyzed for anomalous behavior
- In the case of the Tohoku-oki earthquake, the Japanese GPS network, one of the densest in the world, could be seen changing state as a result of the propagation of the seismic waves through the network
- Analysis of large data sets allows us to see behavior of networks such as these, expanding datasets into interpretation of tectonic (or non-tectonic) effects



Earthquakes

A Brief History…

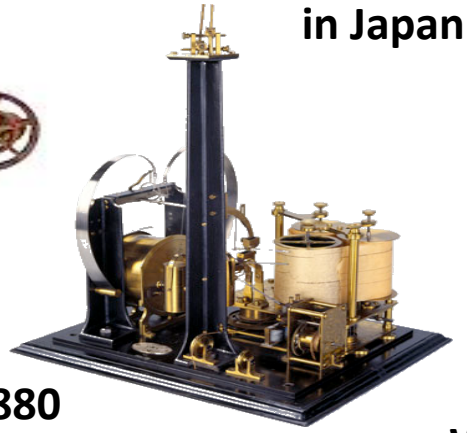
Luigi Palmieri, Italy



1855
Time, Duration
Intensity

China Seismometer

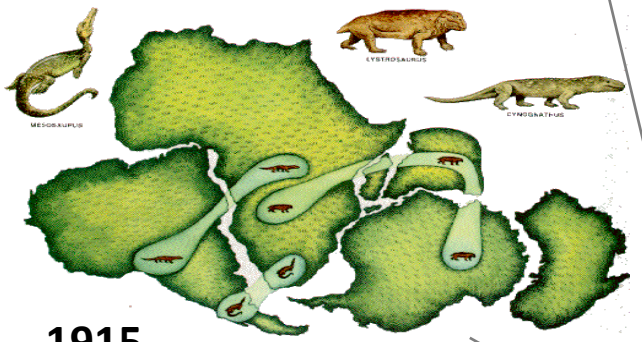
132
Direction



Milne, Ewing, Gray: British professors in Japan

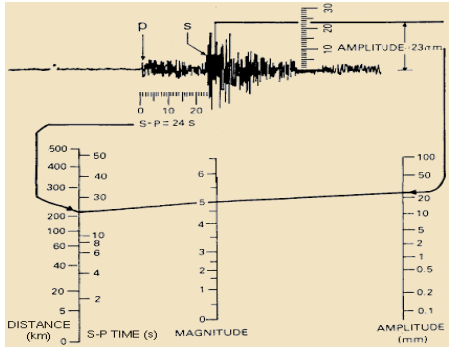
1880
Waveforms

Wegner



1915
Continental Drift

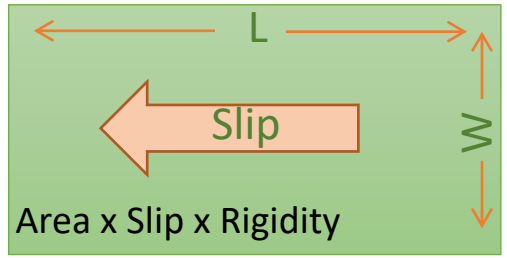
Richter Scale



1935
Intensity of earthquake

1984
Measured plate tectonics

Hanks & Kanamori



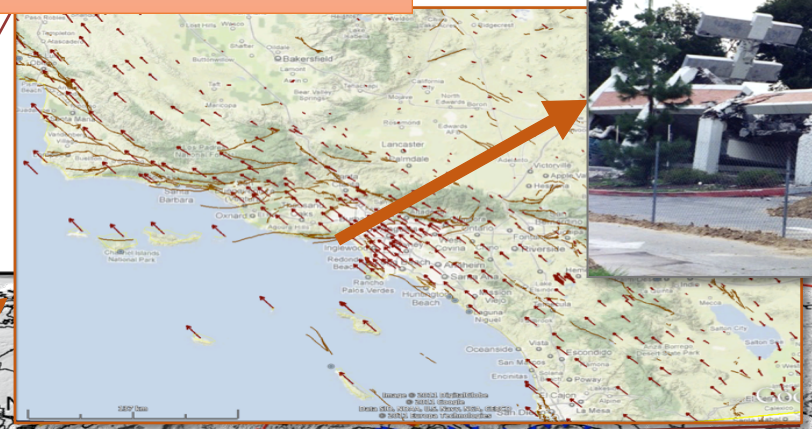
1979
Moment Magnitude

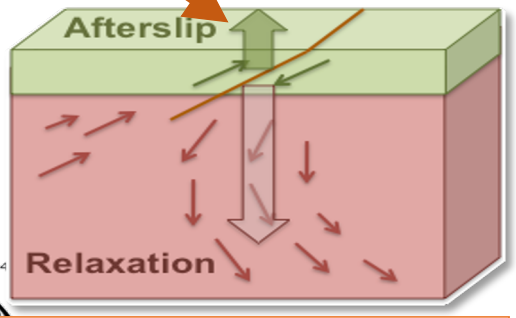
AD
0
500
1000
1500
2000

Earthquakes Occur Over Many Timescales

Strain accumulation – kilometers/decades

Earthquakes – nucleate over meters/milliseconds





Postseismic adjustment – kilometer/month scales

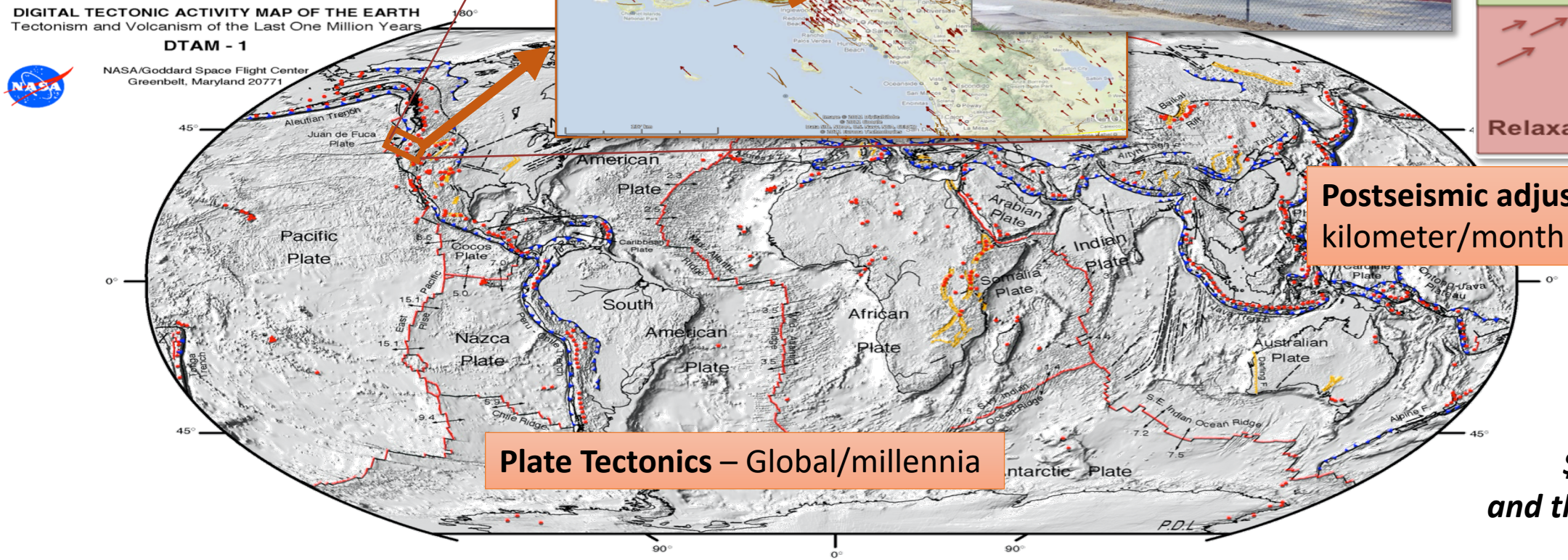
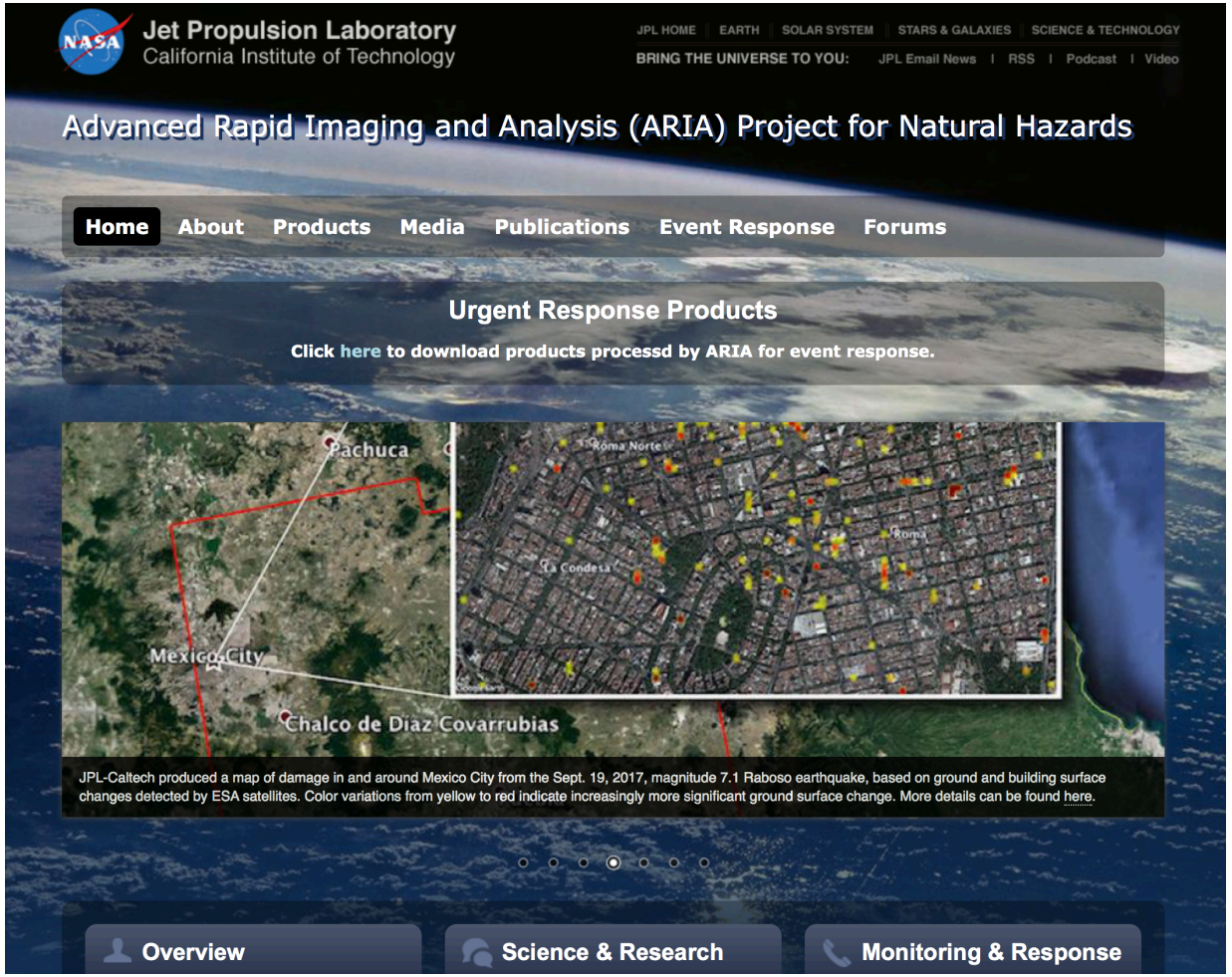


Plate Tectonics – Global/millennia

Magnitude 7 in California: $200-300B losses and thousands of lives

ARIA – Advanced Rapid Imaging and Analysis



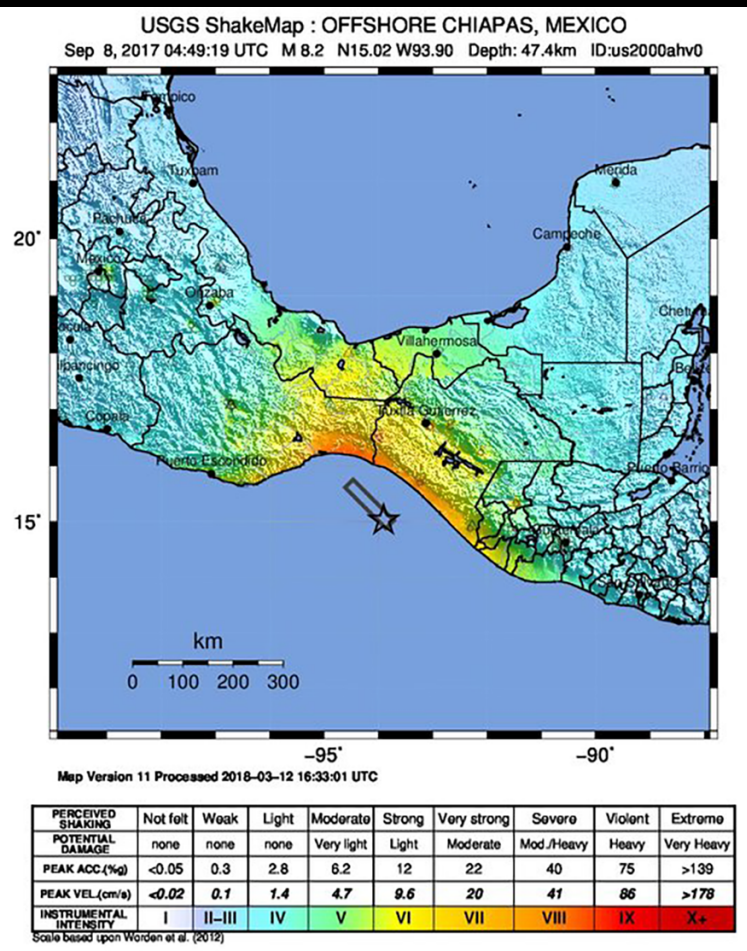
- ARIA is a collaboration between JPL and Caltech to exploit radar and optical remote sensing, GPS, and seismic observations for hazard science and response.
- ARIA investigates the processes and impacts of earthquakes, volcanoes, landslides, fires, subsurface fluid movement and other natural hazards by applying modern geodesy, merged with ground-based observations, to help improve our resilience to such events.
- The project develops state-of-the-art ground deformation measurements change detection methods and physical models using GPS and synthetic aperture radar observations, automating the required large-scale processing, and producing basic data products for the science community.

2017 Mexico Earthquakes

The 8 September M 8.1 Tehuantepec earthquake, the largest earthquake recorded in Mexico over the last 100 years, and the 19 September M 7.1 Puebla earthquakes both caused widespread damage, affecting several million people and causing numerous casualties.

A NASA Disasters team activated soon after these devastating earthquakes in order to support decision makers in Mexico, using NASA modeling and international remote sensing capabilities to generate decision support products to aid in response and recovery.

M 8.1 Tehuantepec Earthquake



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

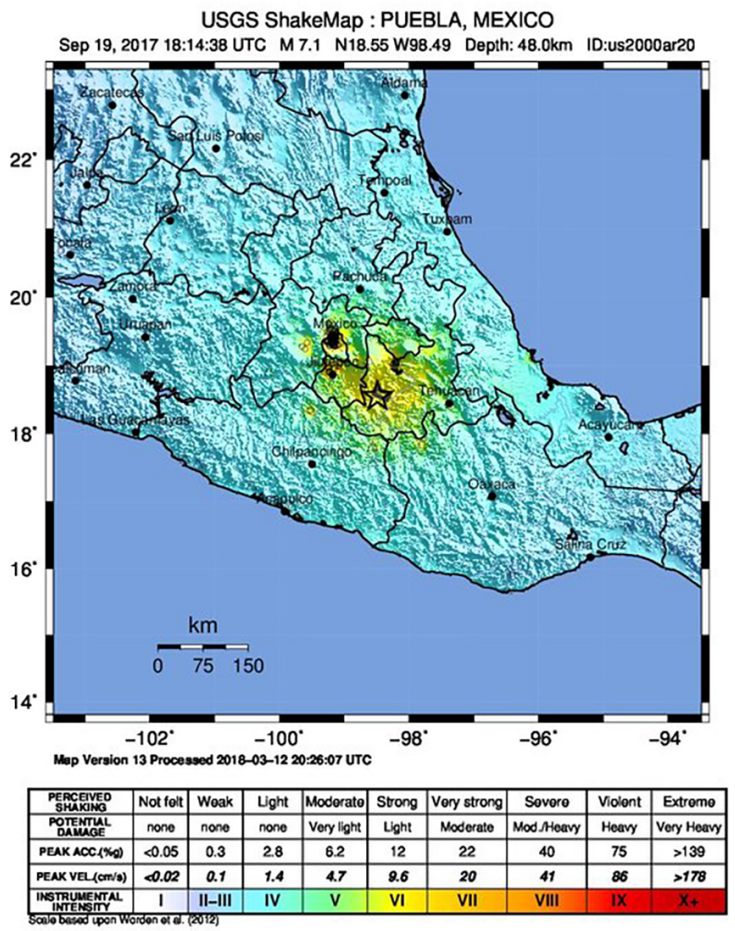
Scale based upon Worden et al. (2012)

The 8 September M 8.1 Tehuantepec earthquake was the largest earthquake recorded in Mexico over the last 100 years

It generated a tsunami and several aftershocks, affected millions of people damaged thousands of homes, and caused nearly 100 casualties.

Pictured above, Mexico's former President Enrique Peña Nieto is inspecting damage to a home in Juchitán, Oaxaca

M 7.1 Puebla Earthquake



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INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

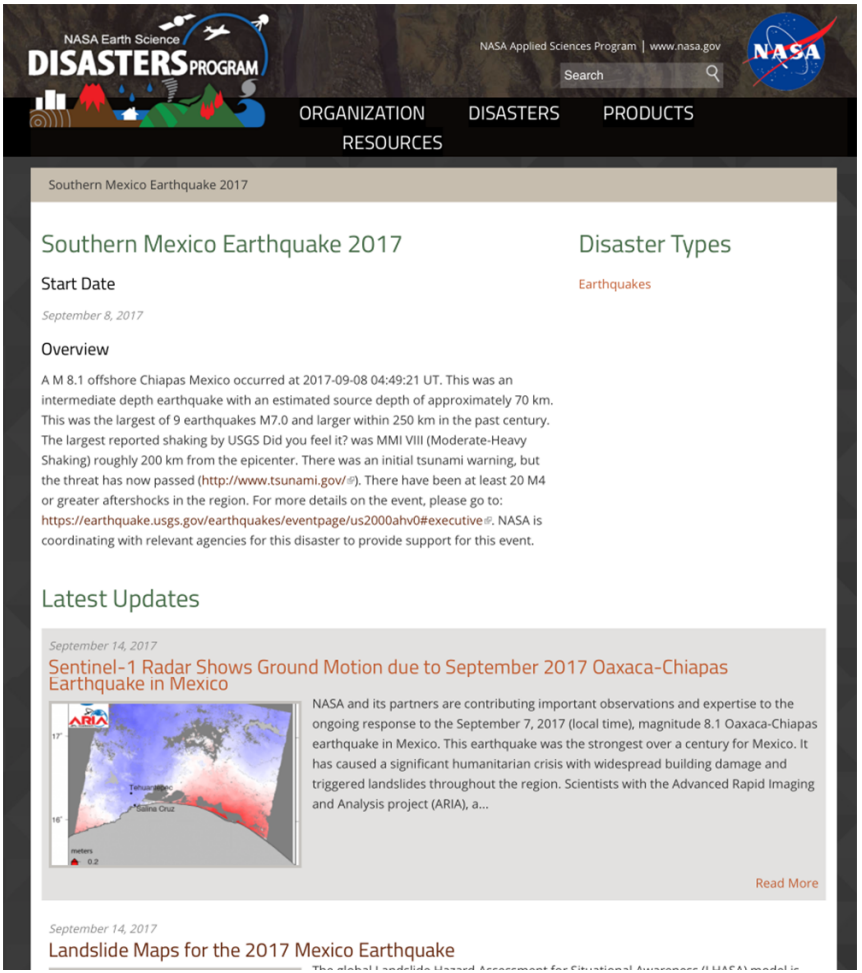
Scale based upon Worden et al. (2012)

Just over a week later, the Puebla earthquake struck on 19 September 2017, causing numerous fatalities, building collapses and widespread damage.

The earthquake damaged buildings in the states of Puebla and Morelos as well as in Mexico City.

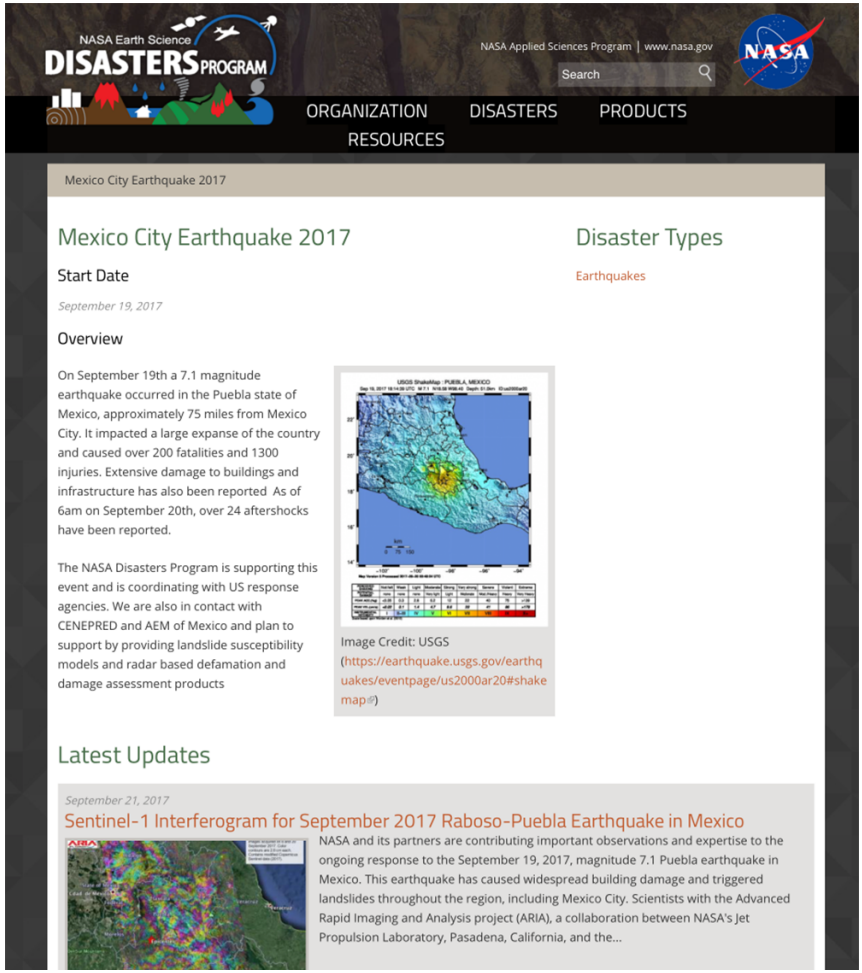
The picture above shows a collapsed building in Mexico City.

NASA Earth Sciences Disasters Program Support



The Disasters Program website offers information about the Program, as well as event activations. Individual events have pages where summary information and products are listed.

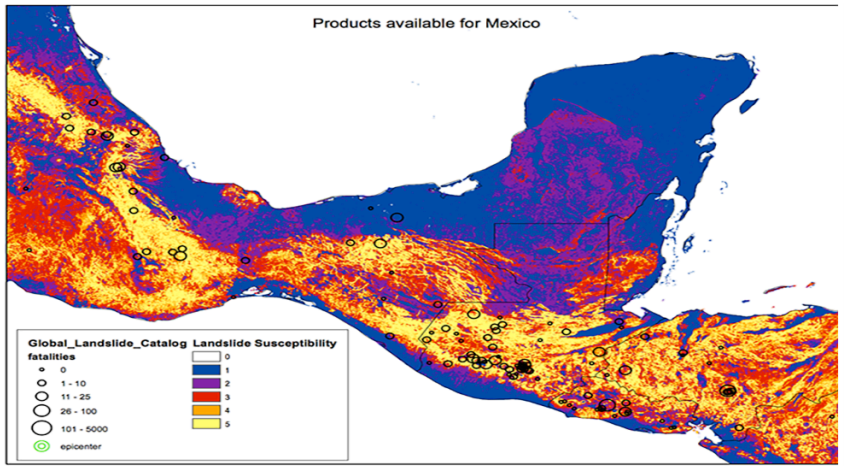
The Disasters Program activated for the two September 2017 earthquakes. Event pages were created for each with summaries and products. The Program supported both domestic and international partners responding to the event. We worked with Mexico's space agency (AEM), the National Center for Prevention of Disasters (CENAPRED), and NASA scientists. We also worked with academic partners, technical institutions, and field responders, including the USGS and OFDA.



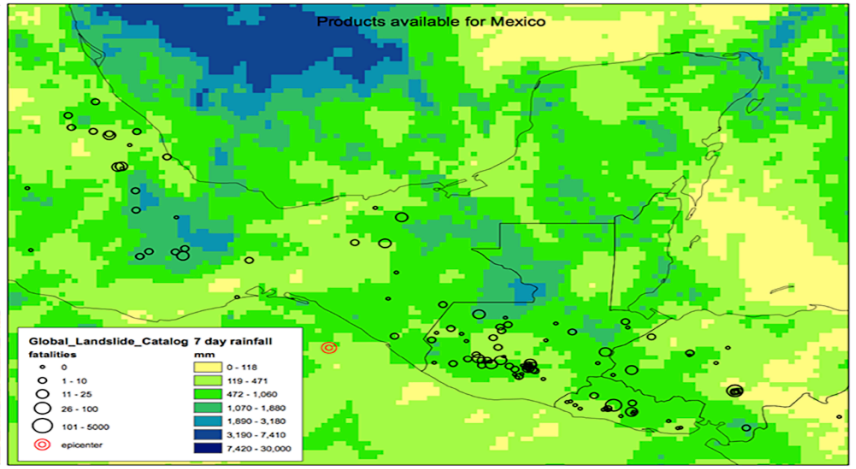
https://disasters.nasa.gov/mexico-earthquake-2017

https://disasters.nasa.gov/mexico-city-earthquake-2017

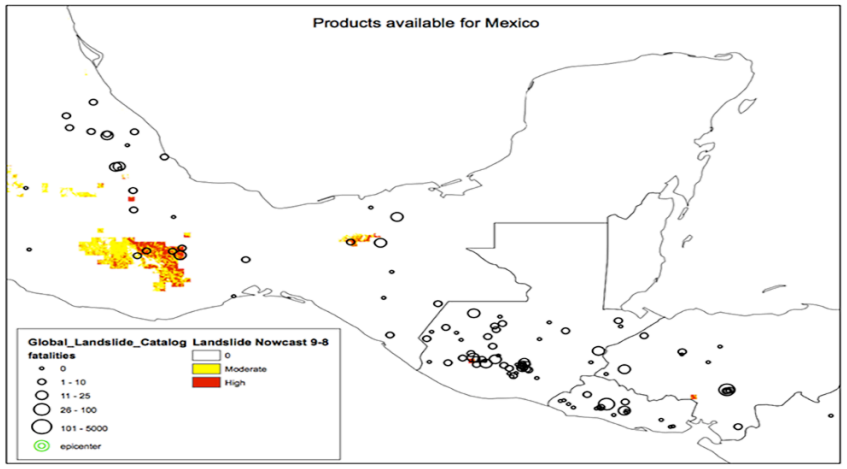
Landslide Models



The global Landslide Hazard Assessment for Situational Awareness (LHASA) model is developed to provide situational awareness of landslide hazards for a wide range of users.



Precipitation is a common trigger of landslides. The GPM Integrated Multi-satellite Retrievals for GPM (IMERG) data shows recent precipitation, updated every thirty minutes.



A LHASA landslide “nowcast” is created by comparing GPM data from the last seven days to the long-term precipitation record provided by the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA).

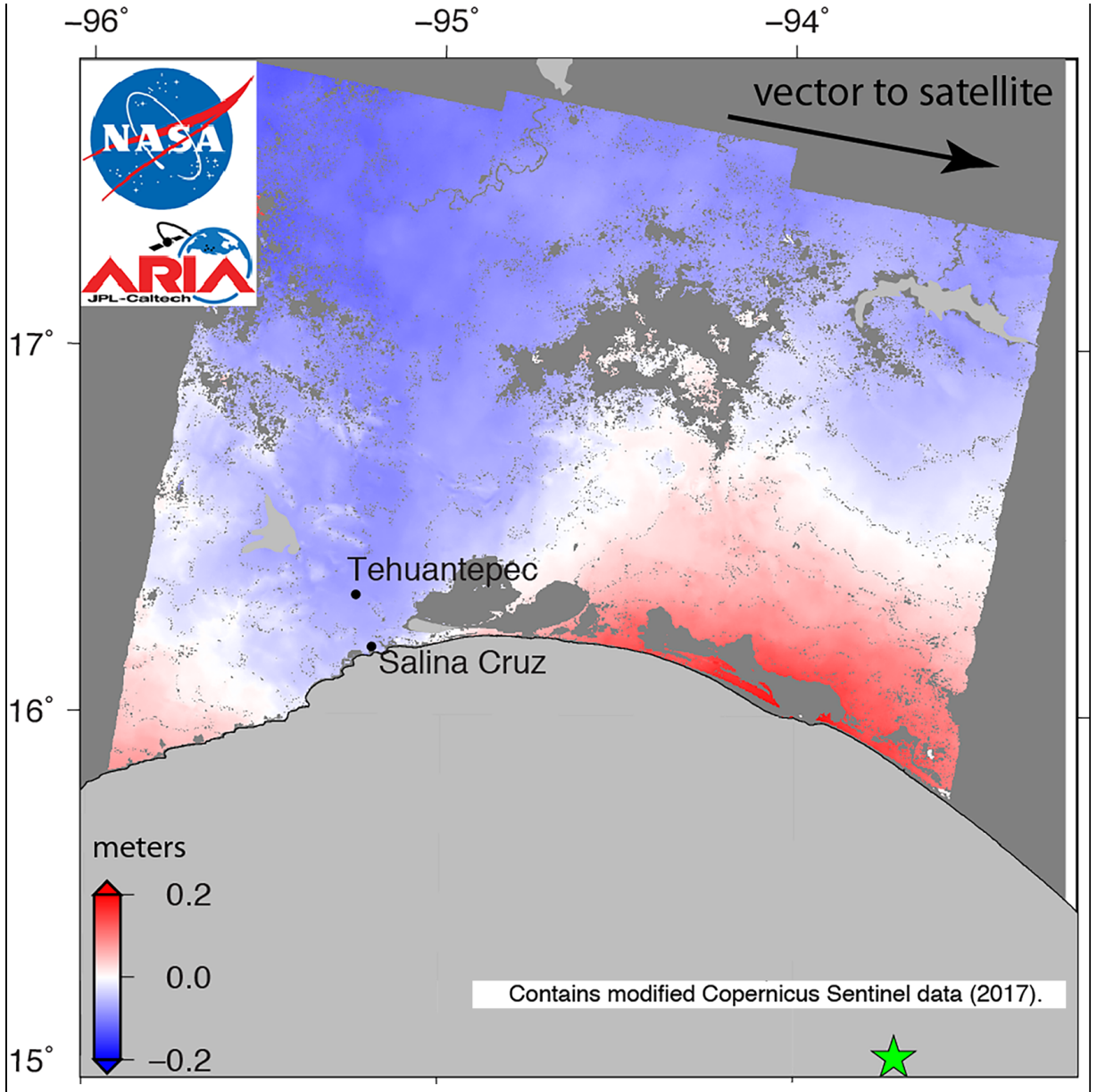
CENAPRED analyzed the landslide susceptibility and nowcast data and integrated them into their "National Risk Atlas" visualization system. **https://disasters.nasa.gov/mexico-earthquake-2017/landslide-maps-2017-mexico-earthquake**

Products generated by the Disasters Program were used by AEM in collaboration with other government agencies in Mexico to make appropriate decisions for mapping damage, rescue and recovery, and informing the population regarding areas prone to potential risk.

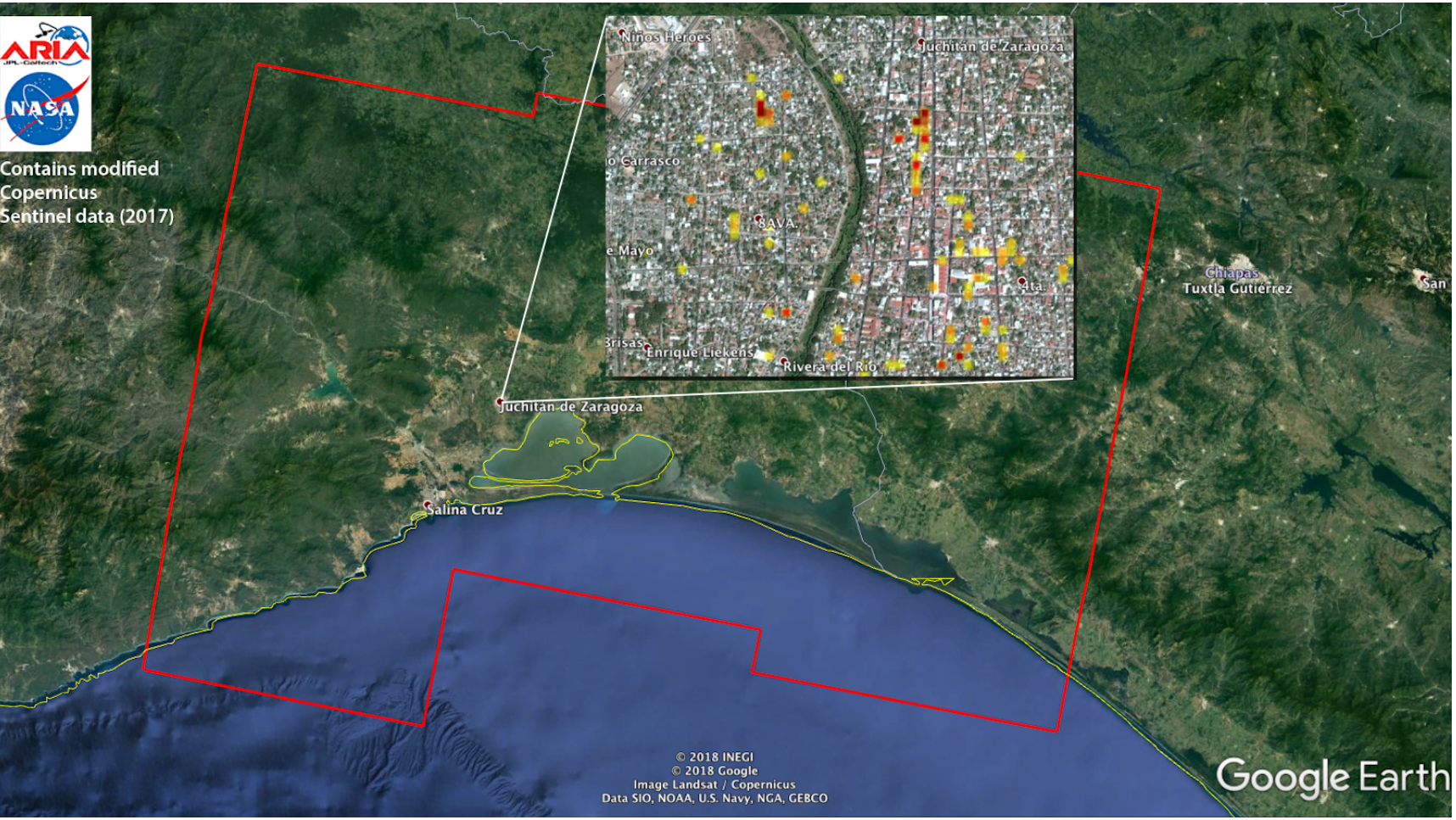
ARIA Deformation Map of Tehuantepec Earthquake

Scientists with ARIA analyzed interferometric synthetic aperture radar images from the radar instrument on the Copernicus Sentinel-1A and Sentinel-1B satellites, operated by the European Space Agency (ESA), to calculate maps of the deformation of Earth's surface. This false-color map shows the amount of permanent surface movement caused almost entirely by the earthquake, as viewed by the satellite, during a 6-day interval between radar images acquired by the two Sentinel-1 satellites on September 7 and September 13, 2017.

https://disasters.nasa.gov/mexico-earthquake-2017/sentinel-1-radar-shows-ground-motion-due-september-2017-oaxaca-chiapas



ARIA Damage Proxy Map of Tehuantepec Earthquake



ARIA created this Damage Proxy Map (DPM) depicting areas of Southern Mexico that are likely damaged as a result of the Chiapas earthquake, shown by red and yellow pixels.

The color variation from yellow to red indicates increasingly more significant ground surface change. Preliminary validation was done by comparing to optical satellite imagery by the DigitalGlobe.

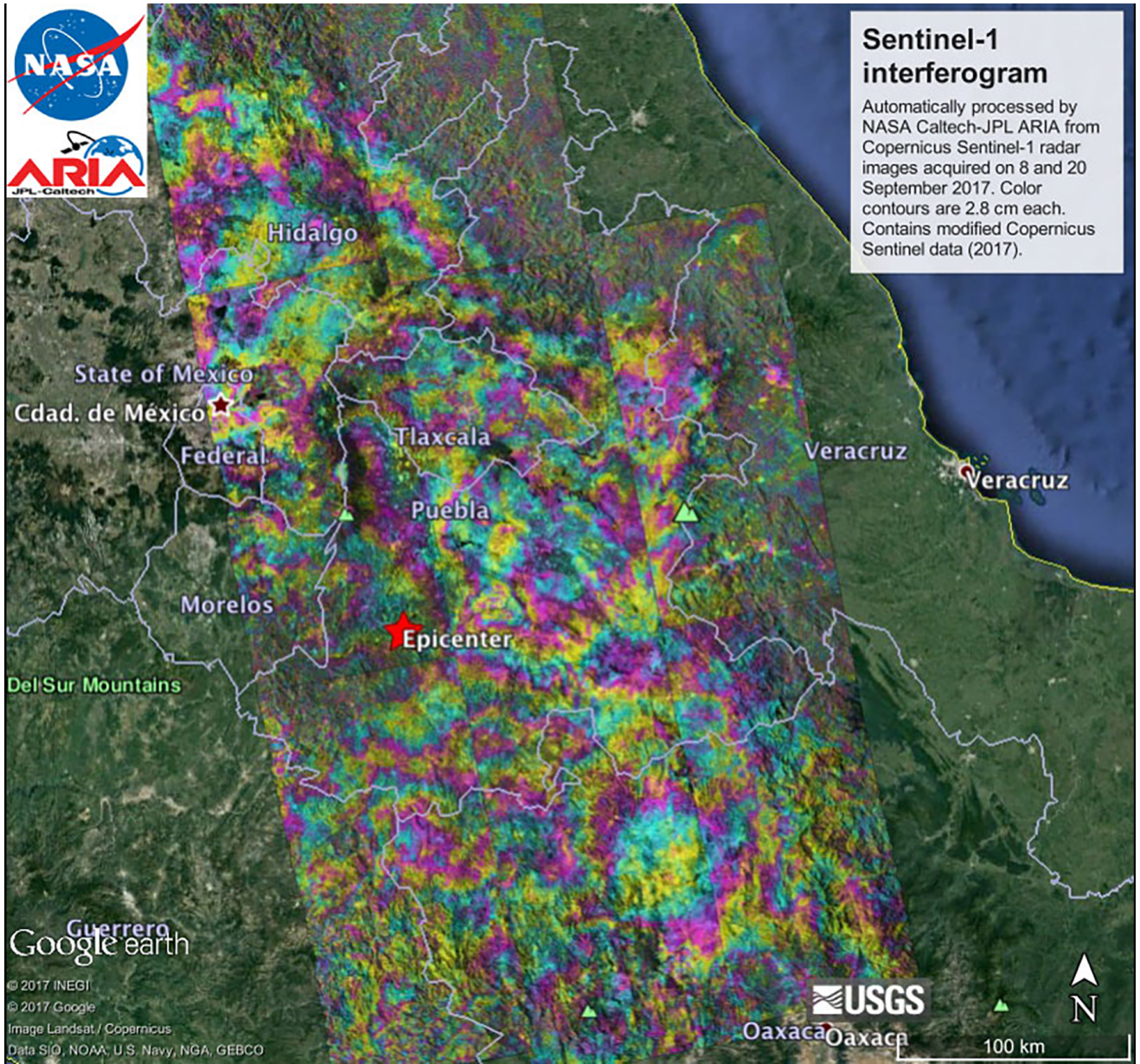
ARIA scientists analyzed images from the radar instrument on the Copernicus Sentinel-1A and Sentinel-1B satellites, operated by the European Space Agency (ESA), to calculate maps of the damage caused by the earthquake.

https://disasters.nasa.gov/mexico-earthquake-2017/satellite-radar-detects-damage-caused-september-2017-m81-chiapas-earthquake

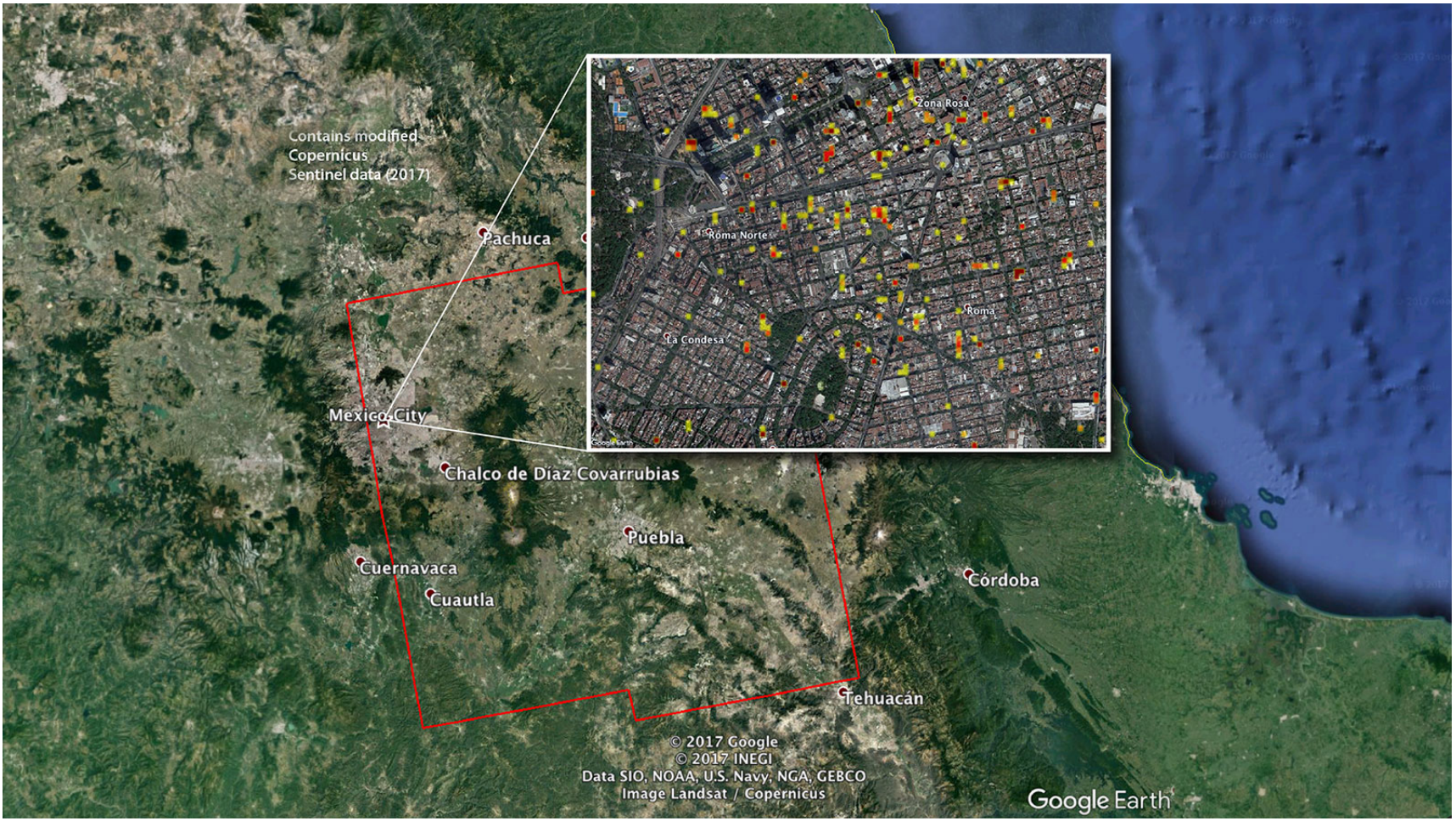
ARIA Interferogram of Puebla Earthquake

ARIA scientists analyzed interferometric synthetic aperture radar images from the radar instrument on the Copernicus Sentinel-1A and Sentinel-1B satellites, operated by the European Space Agency (ESA), to calculate maps of the deformation of Earth's surface. Surface displacements are seen as color contours, where each color cycle
represents 1.1 inches (2.8 centimeters) of surface motion. The contours show there was broad deformation at the surface around 1-2 inches (3-5 cm) and there were no major surface ruptures
due to the earthquake at 30 miles (50 km) depth. Scientists use these maps to build detailed models of the fault slip at depth and associated land movements to better understand the impact on future earthquake activity.

https://disasters.nasa.gov/mexico-city-earthquake-2017/sentinel-1-interferogram-september-2017-raboso-puebla-earthquake-mexico



ARIA Damage Proxy Map of Puebla Earthquake



This image is a Damage Proxy Map (DPM) depicting areas of Central Mexico, including Mexico City, that were likely damaged (shown by red and yellow pixels) from the magnitude 7.1 Raboso earthquake.

The color variation from yellow to red indicates increasingly more significant ground surface change. Preliminary validation was done by comparing the DPM to a crowd-sourced Google Map

ARIA scientists analyzed images from the radar instrument on the Copernicus Sentinel-1A and Sentinel-1B satellites, operated by the European Space Agency (ESA), to calculate maps of the damage caused by the earthquake.

https://disasters.nasa.gov/mexico-city-earthquake-2017/aria-damage-proxy-map-m71-raboso-mexico-earthquake

Letter of Thanks from the Mexican Space Agency

The Disasters Program provided government agencies in Mexico with products that helped inform decisions for response and recovery.

SCT
SECRETARÍA DE COMUNICACIONES Y TRANSPORTES

AEM AGENCIA ESPACIAL MEXICANA

"Año del Centenario de la Promulgación de la Constitución Política de los Estados Unidos Mexicanos"

General Direction
Mexican Space Agency
Mexico City, 6 October 2017

National Aeronautics and Space Administration

On behalf of the Mexican Space Agency I wish to express my most sincere gratitude and appreciation to the National Aeronautics and Space Administration for the support by providing the spatial data related to the earthquakes experienced in Mexico in September 2017, where several regions of our country including Mexico City were severely damaged.

Your valuable contribution through NASA Earth Science Disaster Program, made it possible -in collaboration with other government agencies of Mexico- to take the appropriate decisions for mapping damage, rescuing and eventually recovery of the damage, as well as to address and inform to the population about the affected zones and the areas prone to further risk.

Again, we appreciate your interest and efforts provided by the National Aeronautics and Space Administration to support Mexico.

Sincerely yours,

Dr. Francisco Javier Mendieta Jiménez
General Director

From the General Director of AEM:

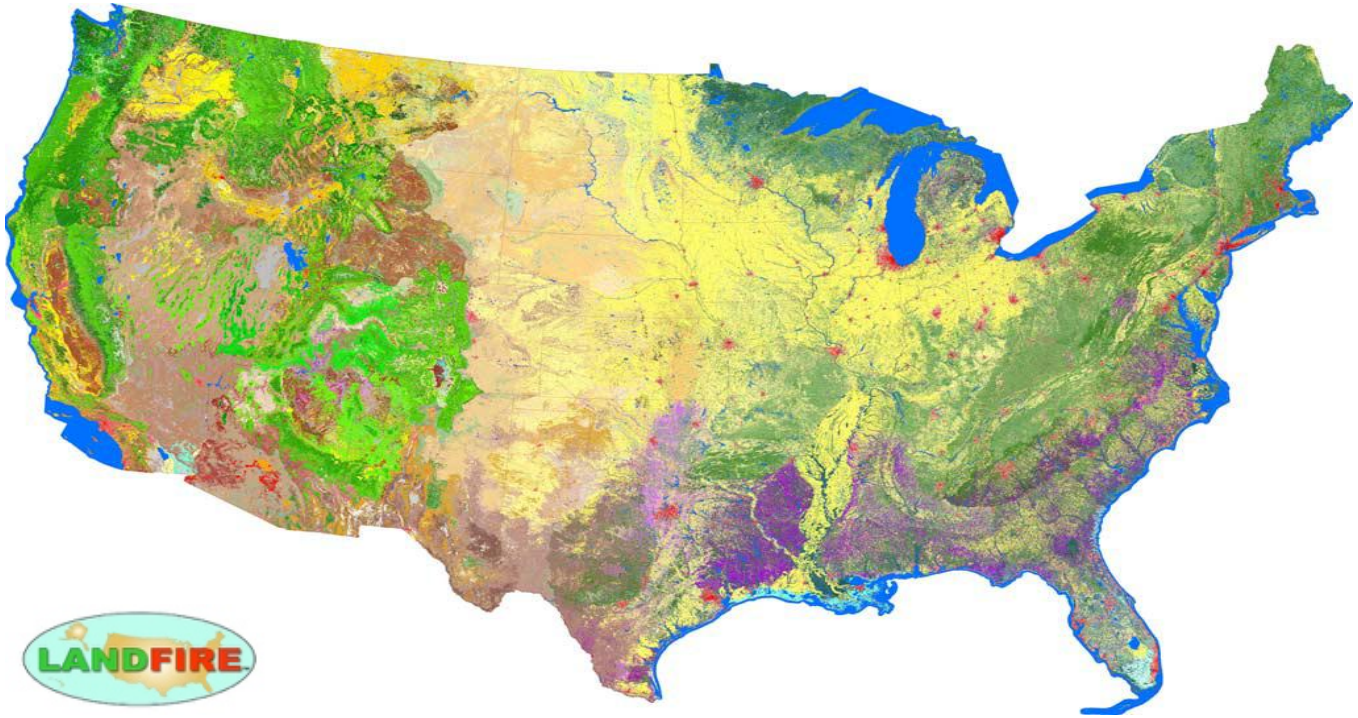
"Your valuable contribution through the NASA Earth Science Disaster Program made it possible – in collaboration with other government agencies in Mexico – to take the appropriate decisions for mapping damage, rescuing and eventually recovery of the damage, as well as to address and inform to the population about the affected zones and the areas prone to further risk."

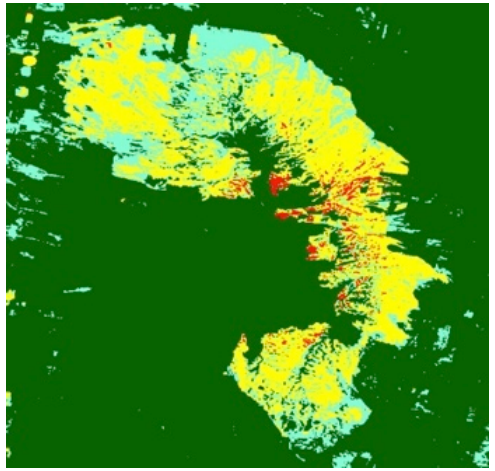
Wildfires

NASA Applied Science: Wildfires

Nine (9) Projects Supporting Wildfire EO

- Pre-Fire Mapping
  - Vegetation density and extent
  - Soil moisture/drought severity
  - Topography
- Active Fire Mapping
  - Total area currently burning
  - Fire Radiative Power (FRP) using thermal bands
- Post-Fire Mapping
  - Total area burned
  - Burn severity
  - Post-fire vegetation regrowth (NDVI)





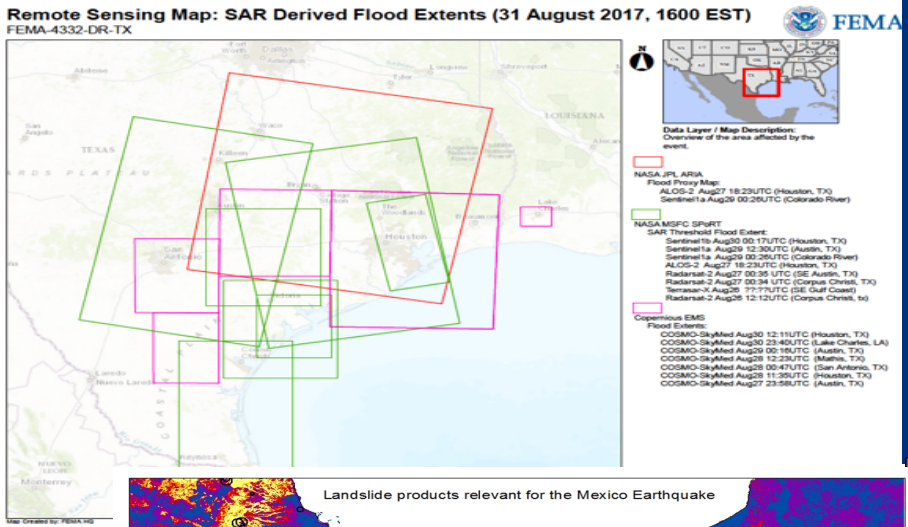
Above: A USGS Landfire map.

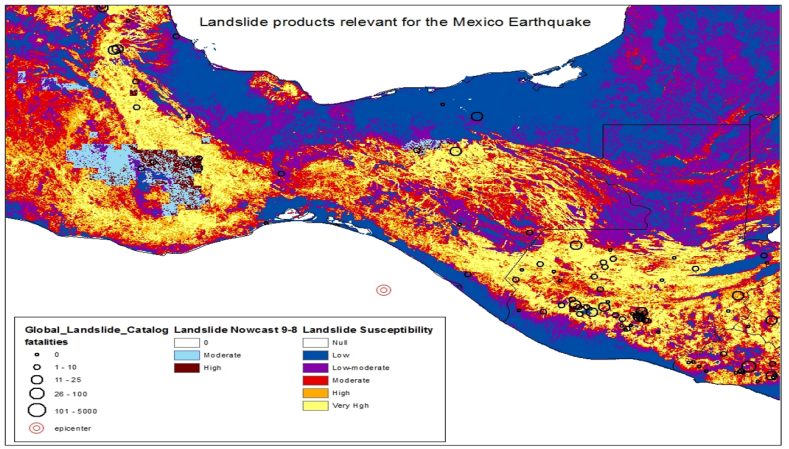
Left: 2007 Black Pine 2 Fire, Idaho, U.S. On the left: imagery, right: burn severity. USDA RSAC.

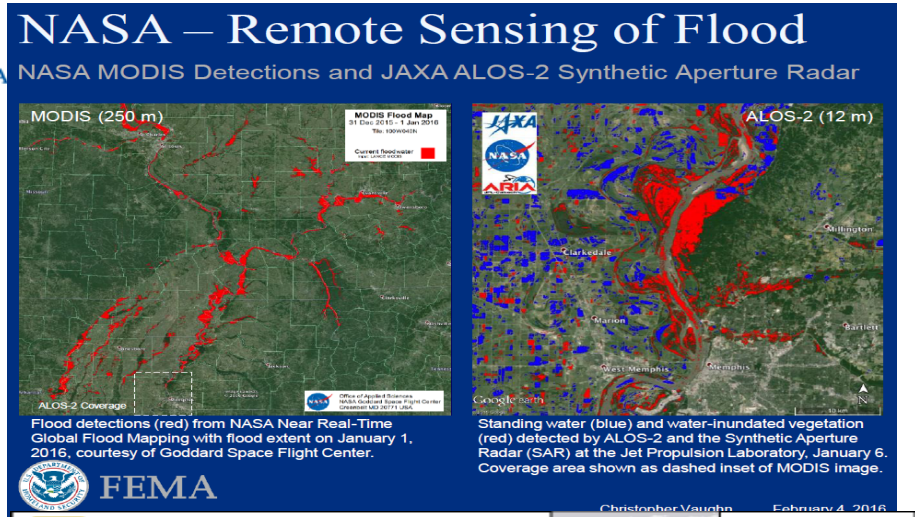
NASA Collaboration and Key Partnerships providing End-to-End Response

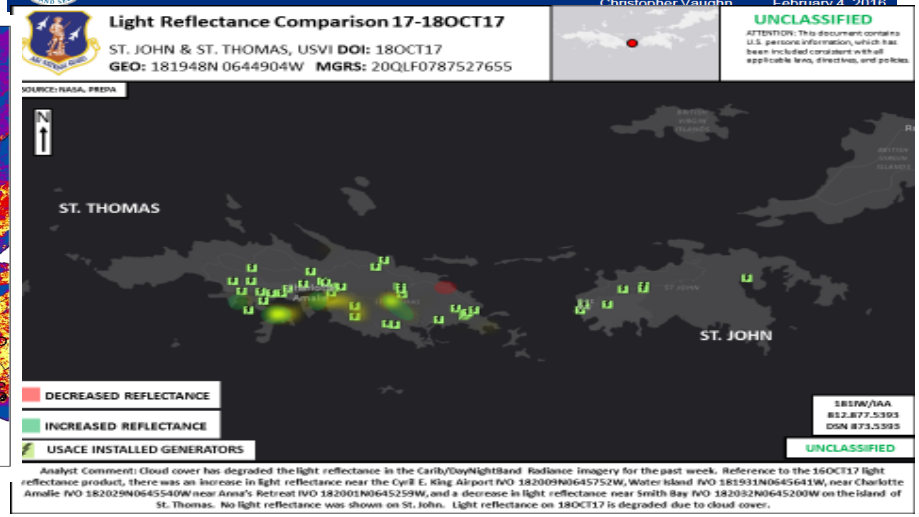
Using Multiple Sensors, Models and Maps to Answer Critical Questions

Mobilizing Resources to Assist Saving Lives and Protecting Property

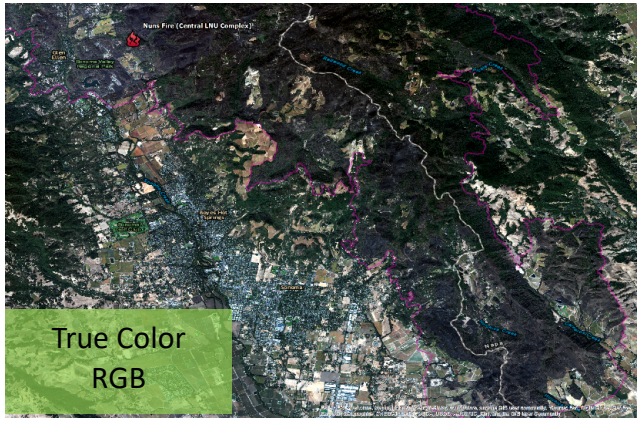




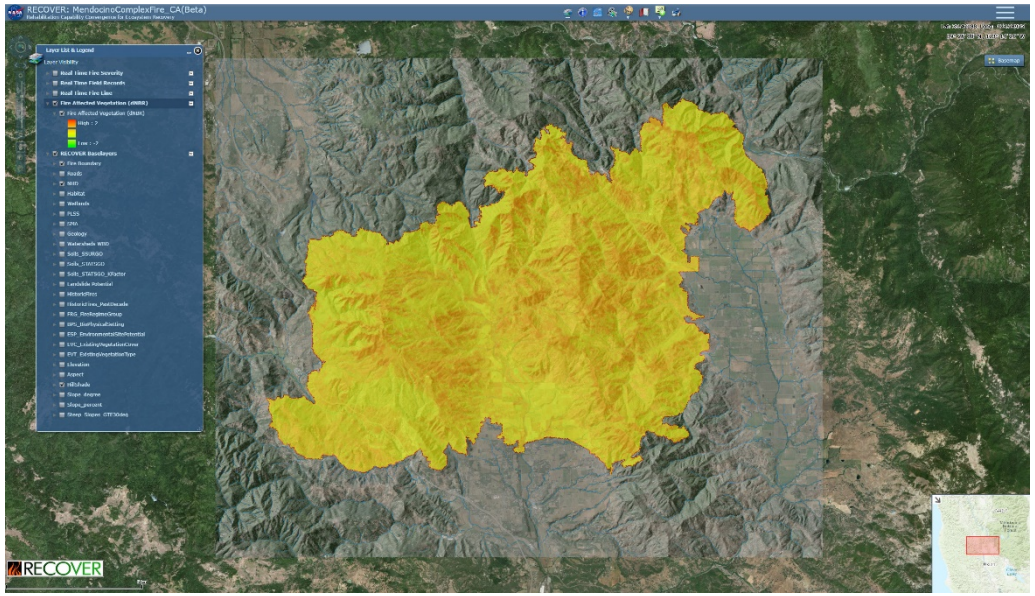




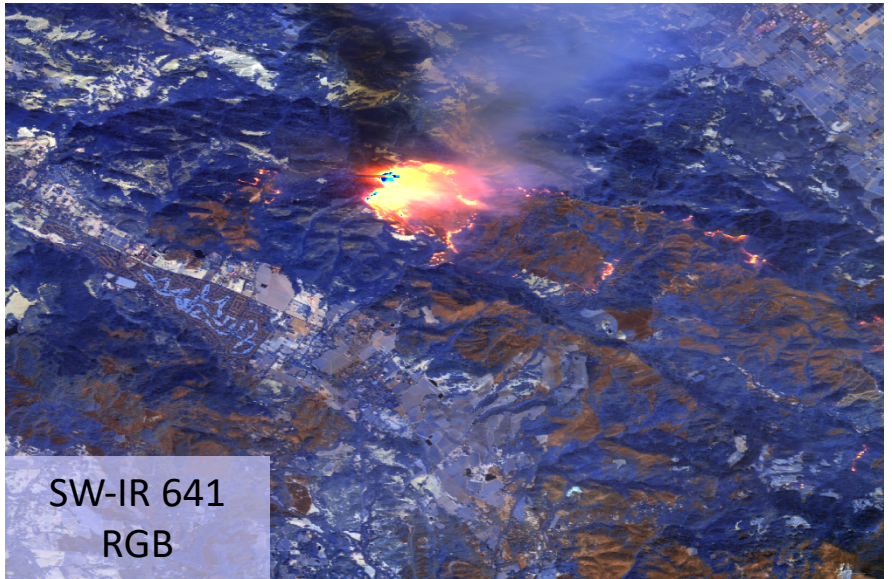
California Fires, October 2017



Digital Globe Worldview imagery RGB processed at NASA Marshall from HDDS downloaded imagery



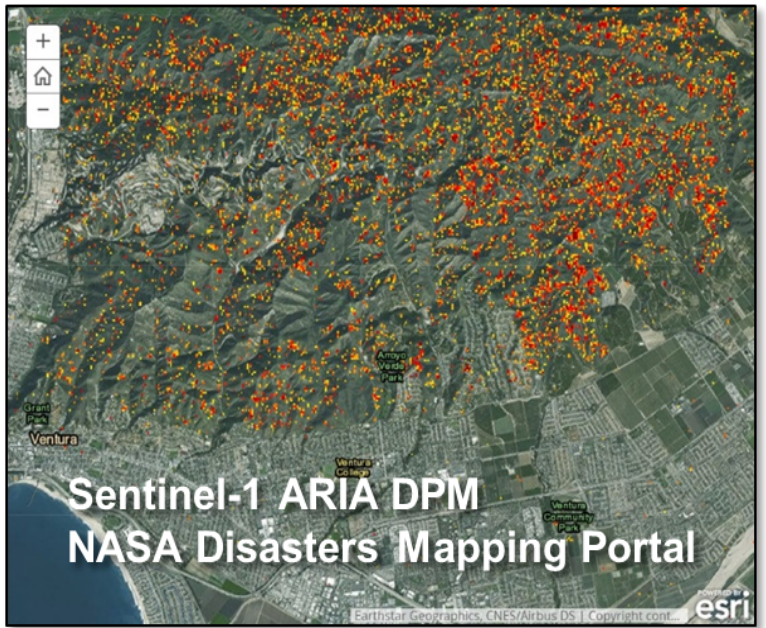
The NASA RECOVER DSS rapidly assembled dozens of GIS layers and earth observation imagery to provide fire fighters and managers with actionable information to respond to California's wildfires http://giscenter.isu.edu/research/Techpg/nasa_RECOVER/
The DSS for the Mendocino complex of fires was available in 5 minutes with fire severity imagery (shown on the figure below) added shortly after.

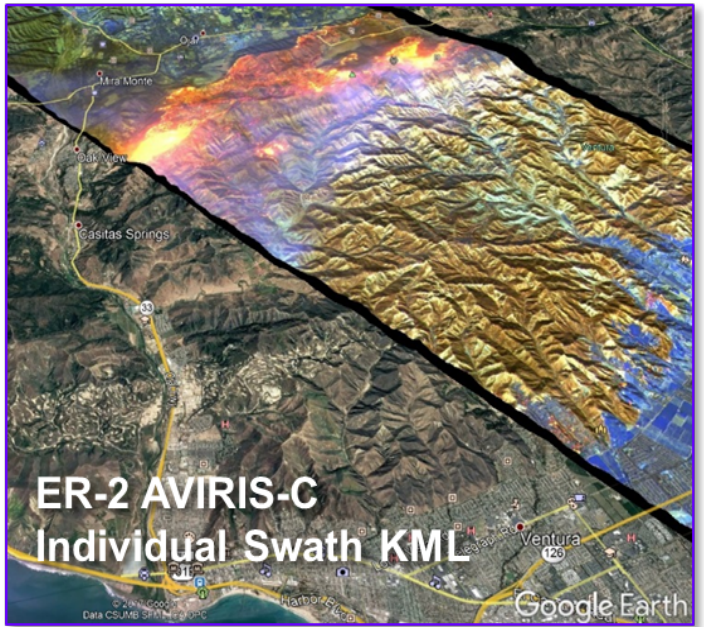


California Fires, December 2017

- Extreme Santa Ana winds contributed to outbreak of 10+ wildfires, including Thomas Fire (Largest officially recorded in California, 281,000 acres).
- NASA scientific data was available but required additional processing into useable formats requested by end users (CalOES, FEMA, NGB J2, CA ANG).

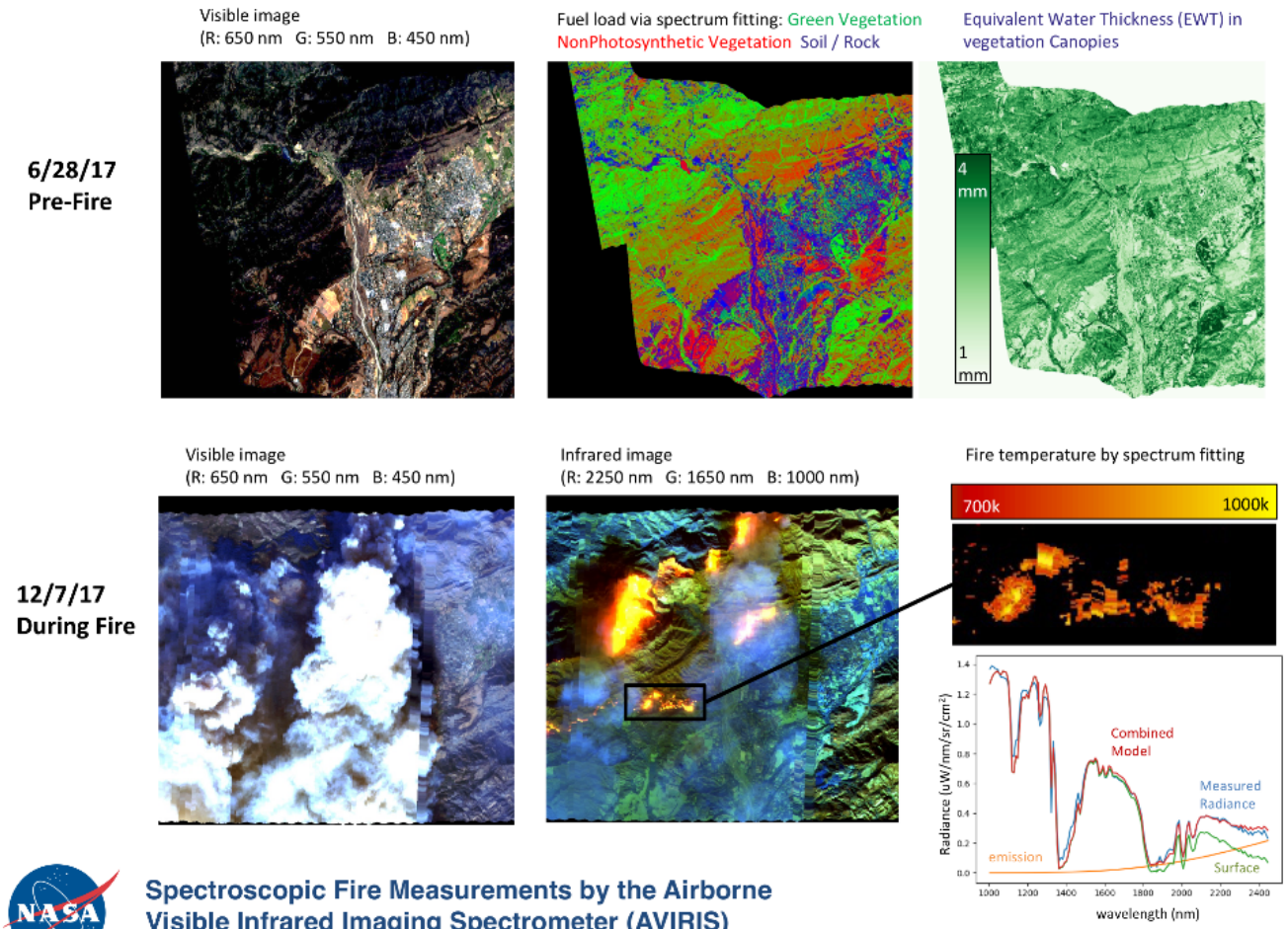
- This response served as a catalyst to improve Program ability to translate valuable scientific data into actionable geospatial information prior to disaster events occurring – ensuring all data we provide is useable and temporally relevant.
- Sentinel-1 ARIA DPM provided to CalOES ER-2 AVIRIS-C provided to NGB/CA ANG

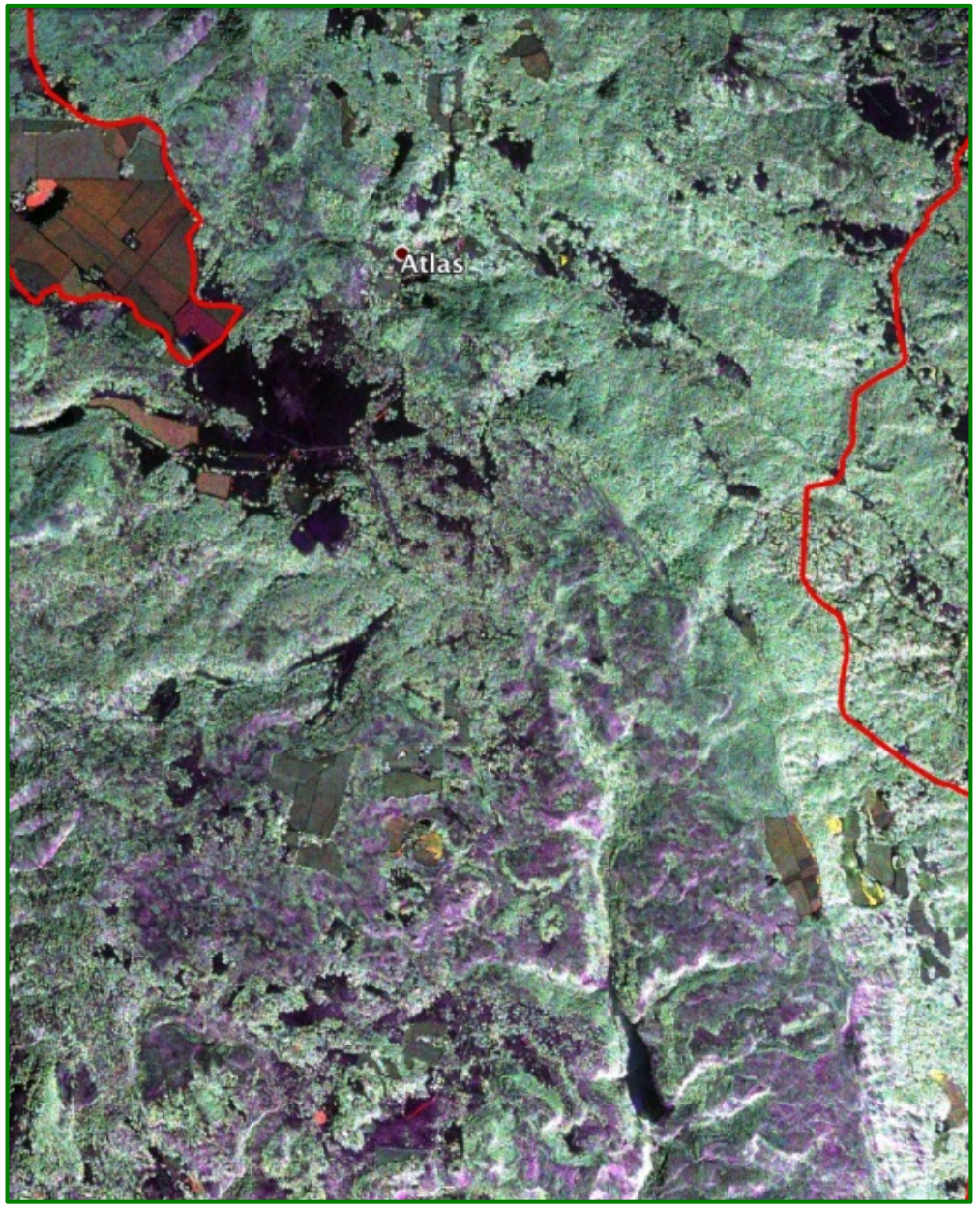




NASA Airborne Science Data

UAVSAR aboard NASA G-III aircraft imaged Napa County, California on October 16 to observe areas affected by several wildfires that started on October 8 and burned thousands of buildings as well as vineyards and forests.





Montecito Debris Flows Observed with UAVSAR

Image Pair

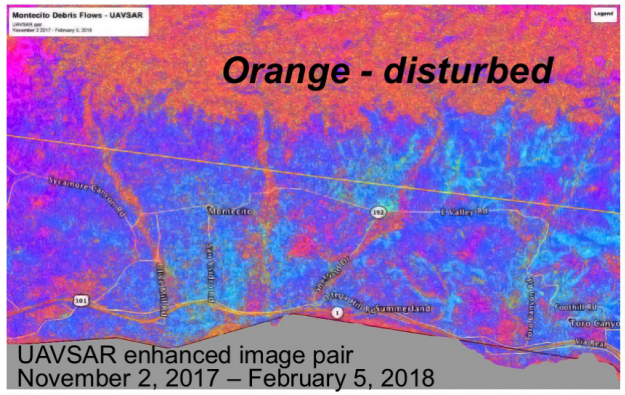
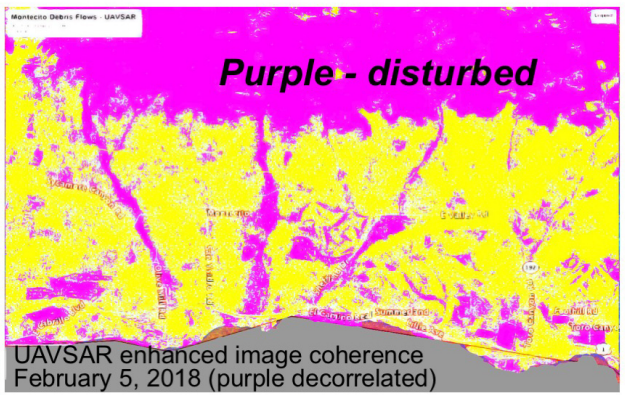
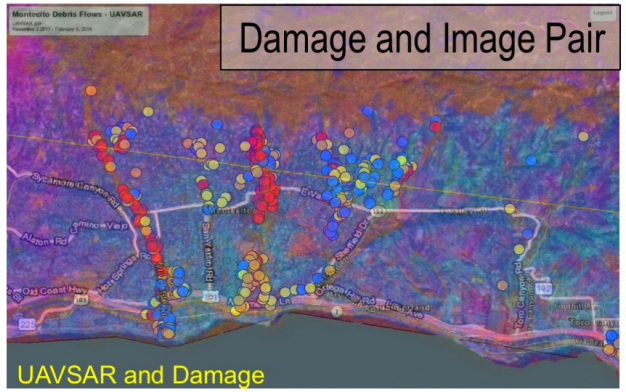
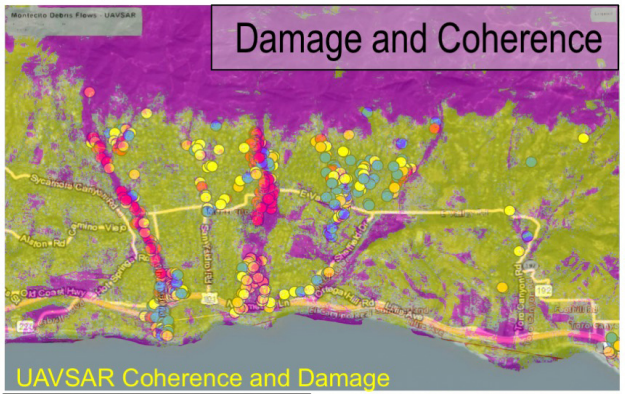
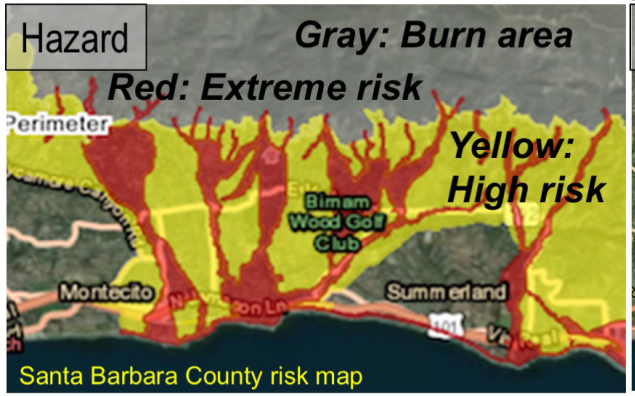


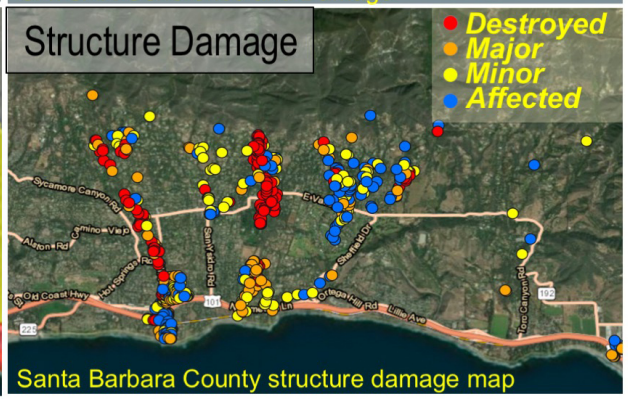
Image Coherence











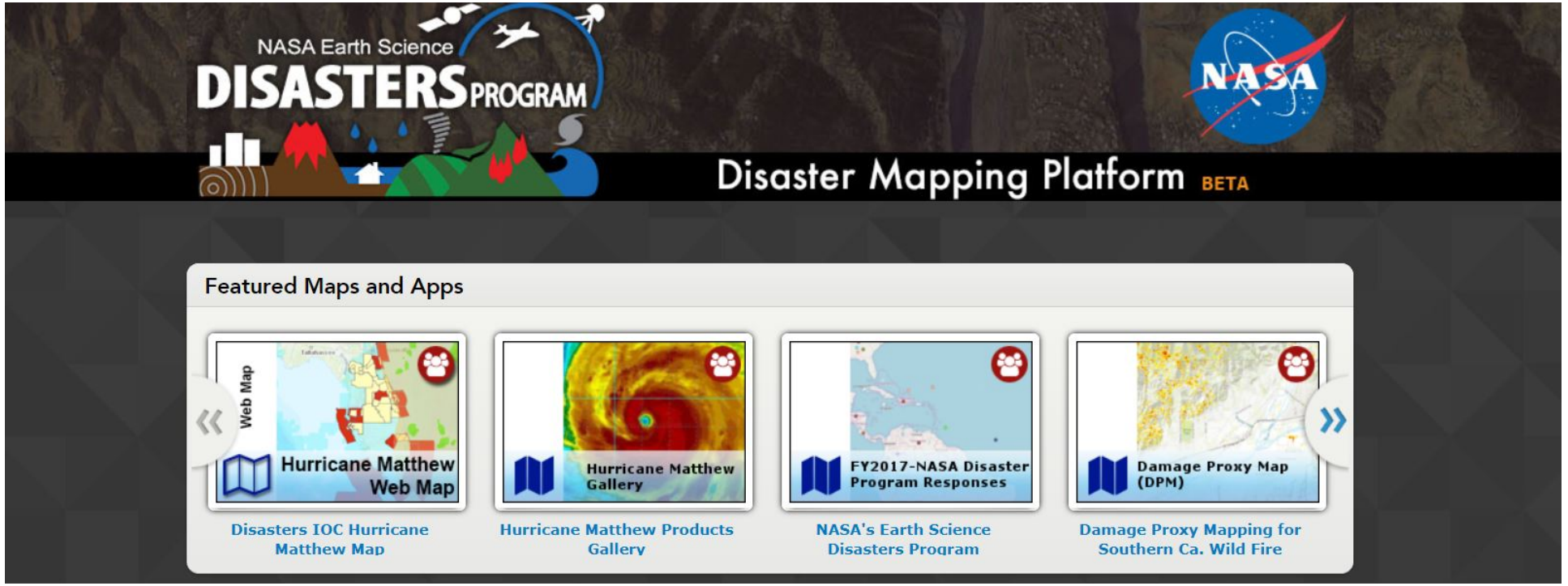
Produced February 9, 2018

Andrea Donnellan, Principal Investigator, NASA/JPL/Caltech

- Extreme winter rains in January 2018 following the Thomas Fire in Ventura and Santa Barbara Counties caused severe debris flows, destroying 73 homes and damaging over 160 structures in the town on Montecito, just east of Santa Barbara.
- NASA UAVSAR airborne radar platform detected changes caused by the debris flows between two images acquired on November 2, 2017 and February 5, 2018.
- An enhanced image pair (top left) show disturbed areas in orange. The two image pairs can't be matched and decorrelate in areas of severe surface disruption from the fire scar and debris flows (top right).
- In the middle panels the radar images are overlaid on the structure damage map produced by the County of Santa Barbara. The fire scars and damage correspond well with the risk map (lower left) and damage map (lower right).
- With an operational system, products such as this have the potential to augment the information available for search and rescue, and for damage assessment for government agencies or for the insurance industries.
- Radar has the advantage of being all-weather with the ability to image through clouds.

Donnellan, et al., 2018

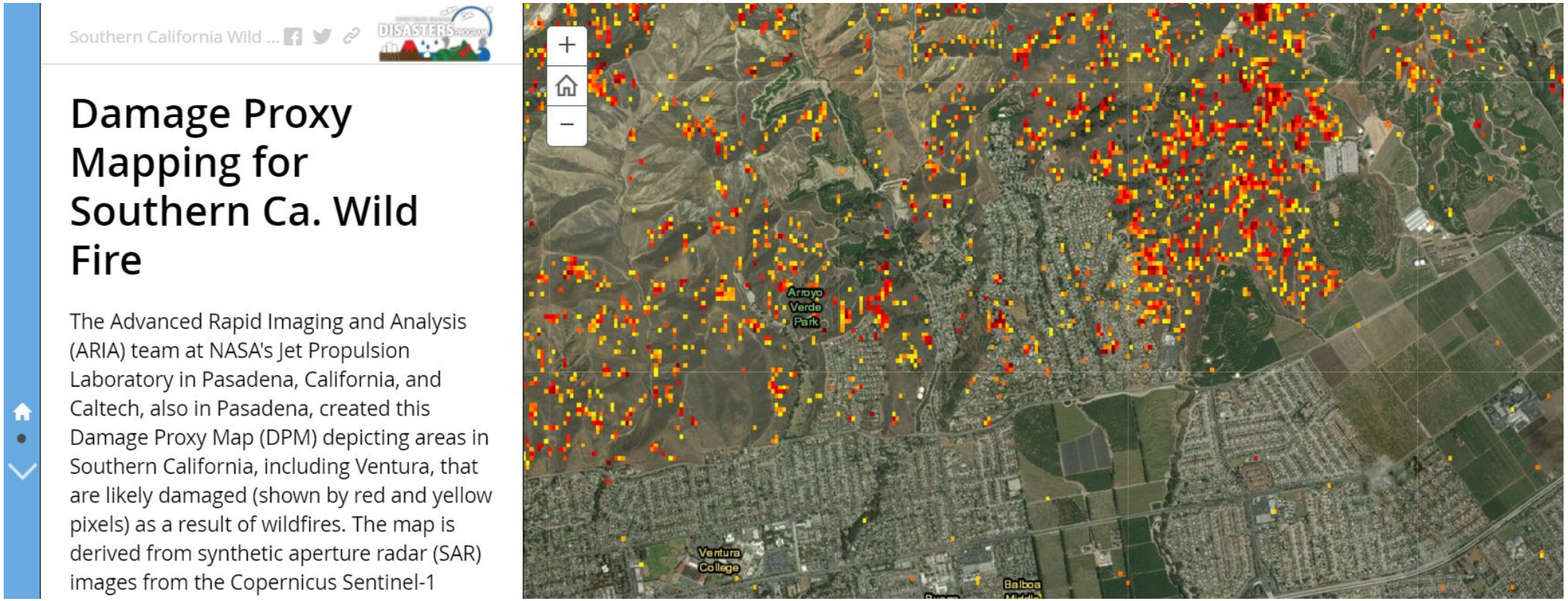
Geospatial Enablement & Data Delivery



The Disasters Program is developing the Disaster Mapping Platform in order to provide ***action-driven geospatial content and capabilities*** *supporting integration, analytics and collaboration across the disaster management landscape.*

https://maps.disasters.nasa.gov

Geospatial Enablement & Data Delivery



*The Disaster Mapping Platform **bridges the gap** between the NASA Science Communities' generated products and the disaster community that could benefit from the data.*

Acknowledgments

Andrea Donnellan, Jay Parker, Sang-Ho Yun, Susan Owen, Hook Hua, Eric Fielding, Cunren Liang, Rashied Amini, Timothy Stough (NASA Jet Propulsion Laboratory)

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Vince Ambrosia, Juan Torres-Pérez (NASA Ames Research Center)

Randy Albertson (NASA Armstrong Flight Research Center)

David Green, J. Carver Struve, Jessica Seepersad, Victoria Thompson (NASA Headquarters)

National Aeronautics and Space Administration

Further Information

https://appliedsciences.nasa.gov/programs/disasters-program

https://appliedsciences.nasa.gov/programs/wildfires-program

https://disasters.nasa.gov

http://geo-gateway.org

https://aria.jpl.nasa.gov

NASA Earth Science
Applied Sciences Program

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